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Technical Investigation
of
Ocean Ranger Accident

Volume 1

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THE HONOURABLE WILLIAM W. MARSHALL, Q.C.
MINISTER

TECHNICAL INVESTIGATION
OF
OCEAN RANGER ACCIDENT

VOLUME I

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EXECUTIVE SUMMARY

The semi-submersible drilling unit, the OCEAN RANGER, was lost on the morning of February 15, 1982 while drilling on the Grand Banks of Newfoundland. The Petroleum Directorate conducted an internal investigation into the technical issues surrounding the accident. The most probable cause of the accident was ascertained after consideration of the various alternatives which presented themselves during the course of the investigation. The conclusions are based on detailed analysis and interpretation of the information available to the study team.

The study team determined that there were two main phases in the accident scenario. The first was the development of a list, the second was the progression of the list which led to capsizing.

The primary findings are:

1. Early in the evening of February 14, 1982, a wave broke a porthole in the ballast control room and water hit the ballast control panel. Some water likely entered the panel and caused shorting of switches and possibly other parts of the electrical system. The shorting of switches and relays may have caused either a valve or valves to open on their own and/or the actual position of a valve or valves to be uncertain to the operator because of a malfunction of the indicator system.

   Any salt remaining inside the ballast control panel after the water had dried could also have caused unpredictable and unreliable behaviour of the panel resulting in the malfunction of valves and/or valve position indicators.

2. There had been no communications of any kind from the OCEAN RANGER for some time prior to the Mayday call at 0100 NST on February 15. This would indicate that there was no perceived ongoing problem with either stability or the ballast control system. Also, the fact that the OCEAN RANGER personnel did not isolate the problem indicates that it was not ongoing. These facts and the rapid sequence of events indicate that an initial bow list of about 5 degrees could have developed quickly, within a time period of an hour or less.

   The list likely developed because of a malfunction of the ballast control system arising from water and/or salt present on or in the ballast control panel as a result of the incident early in the evening of February 14, that is, the breaking of a porthole by a wave.

   The control panel switches likely malfunctioned and one or more valves opened inadvertently and water was transferred from a middle or aft ballast tank in the port pontoon to a forward ballast tank. Based on the ballast configuration before and after the accident, a possible transfer would have been from port WB10 to port WB4. If an attempt was made to pump out WB4, the pumping system would not likely have performed effectively. Water may have been added to port FO12 and starboard FO12 and

DW13 in an attempt to correct the list. Such an action would increase the draft beyond 80 ft.

Port WB1 and starboard WB1 would likely have had ingress of water due to damage to the hull after capsizing took place. (The February 14th configuration shows both tanks empty. The present configuration shows both tanks full).

There is also the possibility that water from the sea may have entered some tanks and/or that water may have transferred from one tank to another during and/or after sinking.

It is possible that the ballast control panel would have been shut down after a problem was noticed. This action should have caused all valves to failsafe close. The list at this time could possibly have been 5-7°. In order to attempt to fix the problem, the panel may have been brought back on with the result that the transfer of ballast forward would have continued ultimately resulting in the 10°-15° list reported in the 0110 NST Mayday. It is likely that the panel would have been shut down permanently by this time. It appears that full power was still available on the rig.

Despite the availability of power, at such a trim forward the ballast pumps would be incapable of transferring ballast water out of the forward tanks. Nor was there sufficient ullage available in the stern tanks to permit restoration of level trim by counterflooding. In other words, it appears that at this point the crew of the OCEAN RANGER may have had no means available to them of trimming the vessel.

The system of manual control of the ballast valves was examined in light of the results of the diving survey conducted in July, 1982 by the Royal Commission into the OCEAN RANGER Disaster. They show that brass control rods had been inserted in positions controlling certain valves. The present investigating team can find no logic to explain why these valves in particular may have been activated. A possible explanation is that the rods were inserted on a general instruction and that there was no set plan for their usage prior to insertion. It is unlikely that the operation of these particular valves would have caused an improvement in the situation. It is unlikely that their operation was a significant contributory factor to the initial development of the list, although their operation may have contributed to the progression of the list and the subsequent capsizing.

3. By 0109 NST on February 15, 1982, the OCEAN RANGER had developed a port bow list of 10°-15°. This was a sufficiently severe list under the existing wave conditions to initiate downflooding of the forward port chain locker. The increase in forward trim also caused the forward starboard chain locker to flood.

   It appears that at approximately 0130 NST the crew ceased in their attempt to correct the situation and abandoned the rig.

The progressive flooding eventually gave the rig such a forward trim that, by approximately 0245 NST, the helideck was intermittently immersed.

Both the forward chain lockers continued to fill causing the upper hull to be immersed and flooded. This brought the rig to an unstable position and it capsized. The time of capsizing is estimated to be between 0300 NST and 0310 NST based upon radar observations onboard the NORDERTOR. In the space of about one minute, the image of the rig disappeared from the radar screen, reappeared briefly as two oval blips, then disappeared for good.

The momentum of the rig and the increased wave forces during capsize caused the breakage of the forward mooring lines. Due to the size of the rig and the water depth, the forward ends of the pontoons likely scraped the seafloor damaging the anchor bolsters and forward trim tanks. Breakage of the forward mooring lines drew the rig downwind toward the intact mooring lines until the rig settled upside down on the bottom.

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INTRODUCTION

The semi-submersible drilling unit, the OCEAN RANGER, was lost on the morning of February 15, 1982 while drilling on the Grand Banks of Newfoundland. There were no survivors and there is a lack of hard knowledge of the events surrounding the accident.

The Petroleum Directorate, because of its regulatory responsibilities for offshore safety, undertook an extensive investigation of the accident with emphasis on technical issues. The present report is the result of that work.

The objective of the investigation was to ascertain the most probable cause of the sinking of the OCEAN RANGER with the intention of incorporating the findings into regulations as appropriate.

The Directorate was assisted by expert consultants both in the development of possible accident scenarios and in the detailed analysis. The Directorate received cooperation from the owner of the OCEAN RANGER and the operator holding the drilling permit.

CHAPTER 1 GENERAL DESCRIPTION OF UNIT AND PROCEDURES

1.1 General Description

The OCEAN RANGER was a deep water, self-propelled semi-submersible drilling platform owned by the Ocean Drilling and Exploration Company (ODECO) built by Mitsubishi Heavy Industries, Japan. The structure was American Bureau of Shipping (ABS) classed for unrestricted ocean operations.

The vessel was 398.4 ft. long and 262 ft. wide, with a 14,000-horsepower propulsion system. It was of twin hull design, consisting of two pontoons (cross section of 62 x 24 ft.) with the deck supported by four 38 ft. diameter tapered to 36 ft. and four 25 ft. diameter tapered to 18 ft. stabilizing columns. An isometric view is given in Figure 1.1 and general configuration and profile in Figures 1.2 and 1.3. Four horizontal braces, two of them 12 ft. in diameter and the other two 14 ft. in diameter, two diagonal trusses 7 ft. in diameter and four vertical trusses 7 ft. in diameter were the other primary structural members. All the horizontal truss members were free flooding while the diagonal and vertical truss members were watertight.

The vessel was maintained in position by a 12 line mooring system. The OCEAN RANGER could accommodate 100 men it its living quarters. It was designed to drill at 80 ft. draft in water depths up to 3,000 ft. when equipped with 5,,600 ft. special wire rope and 3,100 ft. of anchor chain. However, the vessel was equipped with 5,600 ft. of special wire rope and 1,650 ft. of chain enabling it to drill in water depths up to 1500 ft.. Drilling depth capacity was 25,000 ft.; three cranes serviced the deck and pipe racks.

The main characteristics and capabilities of the vessel are given in Table 1.1. The main and lower deck arrangements are given in Figures 1.4 and 1.5. (from ODECO OCEAN RANGER Promotion Book).

1.2 Structural Design Emphasis

The following items were emphasized in the structural design:

- Low stress levels in critical members to provide adequate safety factors for unexpected loadings and to extend fatigue life.
- Use of longitudinal stiffeners in critical members so as not to rely solely on shell plating.
- Use of special steels for improved welding characteristics, for resistance to crack propagation, to reduce probability of brittle fracture, and to reduce probability of lamellar tearing.
- Particular attention to structural detailing to ensure optimum distribution and transfer of loads at connections and to reduce fatigue effects.

- Contour grinding of welds in critical areas to reduce fatigue effects.

- Careful attention to all welding and construction details to avoid notch effects and structural discontinuities leading to fatigue sensitive stress concentrations.

In many cases, general design criteria considerably exceeded regulatory body requirement in effect as of February, 1982.

1.3 Communications and Alarm Systems

The OCEAN RANGER was equipped with a combination communication and alarm system which incorporated telephone communication, paging, general alarm, abandon ship, and all clear signals into one system. Combination telephone and paging tranmitter/receivers were provided at 26 locations and contactors for actuation of emergency tones were provided at 7 locations. The entire system was powered from the emergency generator switchboard with a battery powered source available in case the emergency power failed. There was a hand power communication system located in several key areas throughout the rig. In addition, walkie-talkies were employed by supervisory and key personnel.

Communications to ships and shore were available by use of the equipment listed in Table 1.2. A 24-hour radio watch was maintained at the Mobil shore base and a working hours watch maintained at the ODECO shore base, both located in St. John's.

1.4 Certificates

The following certificates and reports were issued to the OCEAN RANGER:

Type	Survey Date	Issue Date	Expiry Date
International Load Line Certificate	5 July 1979	30 October 1980	5 July 1984
Report of Annual Load Line Inspection	16 June 1981	16 June 1981	-
Provisional Load Line Certificate	16 June 1981	16 June 1981	16 November 1981
Cargo Ship Safety Construction Certificate	-	28 April 1980	31 July 1984
Cargo Ship Safety Radiotelegraphy Certificate	-	16 April 1981	15 April 1982
Cargo Gear Certificate	16 June 1981	16 June 1981	15 June 1982
Certificate of Registry	N/A	5 August 1980	N/A
MVI Inspection Record on Special Hull Survey	April 1980	29 April 1980	N/A
Certificate of Inspection	27 Dec. 1979	27 Dec. 1979	27 Dec. 1981
Certificate of Inspection Amendment	N/A	29 April 1980	27 Dec. 1981
Cargo Ship Safety Equipment Certificate	27 Dec. 1979	27 Dec. 1979	27 Dec. 1981
Builder's Certificate	N/A	28 May 1976	N/A

1.5 Work History

The OCEAN RANGER was launched in Japan in May 1976. She drilled in the Gulf of Alaska for 15 months and then was stacked in Lower Cook Inlet prior to having some modifications done in Port Alberni. After a tow to the U.S. East Coast, she drilled one well off New Jersey and then was towed to offshore Ireland for another well. She then came to Newfoundland, where she was drilling her fourth well at the time of the sinking. The RANGER's work history is outlined in more detail in Table 1.3, and a summary of significant storms encountered by her in Table 1.4.

1.6 ABS Approved Limiting Environmental Conditions

Draft	Wave Height	Period	Current	Wind Velocity	Live Deck Load
55-80 ft	110 ft.	15 sec.	3 knots	100 knots	4000 L. Tons
55-80 ft	65 ft.	9 sec.	3 knots	100 knots	4000 L. Tons
up to 30 ft					3650 L. Tons

Steel suitable for temperatures not less than -30°C. (From OCEAN RANGER Booklet of Operating Conditions)

1.7 Hydrodynamic Properties

The following are the hydrodynamic properties of the OCEAN RANGER at drilling draft:

Natural period of Heave:	25 seconds
Natural period of Roll:	50 seconds
Natural period of Pitch:	40 seconds

(From ODECO OCEAN RANGER Promotion Book)

1.8 Operational Limits and Procedures

1.8.1 ODECO Requirements

The Booklet of Operating Conditions for the OCEAN RANGER was for the guidance of the operating personnel in maintaining the unit in a level and stable attitude, to indicate measures necessary for safe operation of the unit (i.e., preparation for a storm, ballasting, etc.) and to indicate remedial measures and precautions in case of serious damage. The booklet was a requirement for classification by the American Bureau of Shipping and for issuance of a load line. It was also a requirement for the United States Coast Guard upon U.S. registry. Key areas in the booklet relevant to the accident are quoted in this section.

1.8.1.1 Responsibilities

The Barge Master or Captain is the "Barge Mover" and is in complete charge of the unit while it is being prepared for a move and is in the process of mooring. The Barge Master is responsible for the stability of the unit at all times. Additionally, he is in charge of the maintenance of the lifesaving equipment and instruction concerning its proper use.

During all industrial operations, the Toolpusher is designated as the person in charge of the unit. He becomes the person in charge once the unit is stationed.

It is the responsibility of the person in charge to:

i) Ensure that the provisions of the Certificate of Inspection are adhered to; and

ii) Be fully cognizant of the provisions in the operating manual.

1.8.1.2 Operating Conditions at Various Drafts

1.8.1.2.1 Operating Condition at 80 Ft. Draft

This condition is at the maximum assigned and allowable draft for operating afloat, which is preferred for operations because motions are least when operating at the deepest draft. Corrected KG is close to the maximum allowable for operating at this draft to meet damage criteria with a 50 knot wind. This draft is, however, suitable for operations by ABS Rule with winds up to 70 knots in an undamaged condition.

In the event winds in excess of 70 knots are forecast the unit, if in this condition, must be deballasted to about 58 ft. draft in order to meet the allowable KG for a 100 knot wind.

1.8.1.2.2 Operating conditions at 75 Ft. Draft

The 75 ft. draft permits a higher deck load than is permissable at 80 ft. draft. The allowable deck load must not be exceeded since the unit would be very "tender" (small GM_L) and thus

(a) have greater inclination due to adding or moving weights on board

(b) have greater pitch or roll in moderate seas

(c) possibly tend to take up a permanent list or trim under the action of large, steep waves.

The placing of lower hull liquids should be optimal for reduction of free surface; if such conditions are not realized in practice the maximum possible deck loads should be reduced.

1.8.1.2.3 Safety Conditions at 58 Ft. Draft

For purposes of the stability calculation, the set back areas are assigned large loads because of the possibility that there may not be time to lay down the loads. Likewise the riser should be indicated as suspended with 75 percent load capacity.

The travelling equipment should be lowered in the guide (i.e., negative moment applied) in order to meet the 100 knot wind storm condition. If necessary, consumables such as salt water, potable water and drill water should be dumped overboard, and fuel oil pumped to the appropriate lower hull tank(s). Liquid mud may be dumped in an extreme situation and compensated by ballast.

1.8.1.3 Measures for Safe Operation

(a) (i) Before any major change is made in loading conditions or ballasting conditions, the unit's stability and trim shall be computed for the new conditions (four hours before a storm). In addition to abiding by various ABS rules concerning stability, ODECO required that the unit must have at least 1.5 feet positive GM (vertical distance between the metacentric height and the center of gravity) in all directions, after correction of KG (vertical distance between the keel and the center of gravity) for free surface, in all operating and safety conditions. In addition, a slight trim stern down will help pump suction.

(ii) Before taking action to correct any unexpected list or trim the cause should first be determined.

(b) All valves, remote and manual, should be opened and closed at least daily to ensure satisfactory operation of limit switches and open/close lights.

(c) The propulsion and pump rooms shall be inspected daily and bilges shall be kept pumped as dry as possible.

(d) The watertight doors at entrance to each propulsion-pump room and watertight hatches at top of each propulsion access trunk must be secured at all times except when actually being used for passage. Caution plates to this effect are affixed to both sides of the doors and hatches and warning lights provided at each location and in the control room. Lights should be checked daily.

(e) All lower hull and column space manhole covers and watertight doors must be fastened at all times except when opened for inspection.

(f) Tanks should be sounded weekly and checked against gauge readings.

1.8.2 Mobil Requirements

Mobil's requirements for operating limits were based upon the amounts of material necessary for a particular operation, and upon resupply capabilities. These requirements are quoted in this section.

1.8.2.1 Operational Limits: Drilling

(a) Sufficient barite will be kept available in bulk and in reserve mud to increase the mass of the mud in the hole and the active system by 120 kg/m^3 (1 PPG). Once on board supplies reach this minimum the bit will be picked up off bottom and the well circulated until sufficient material is available to resume.

(b) Sufficient gel and chemical will be kept on board to completely rebuild the hole volume. Once on board supplies reach this minimum, no further drilling will take place until sufficient material is on board to resume.

(c) Sufficient cement will be kept on board at all times to enable a 1000 ft. plug to be set in open hole, assuming bitsize plus 30 percent.

(d) If on bottom when the operational minimum is reached, tripping will not begin until sufficient material is on board to allow resumption of operations. The well will be circulated in the interim.

(e) If "On the Bank", when operational minimum is reached the pipe will be tripped in and the well circulated until sufficient material is on board to proceed.

1.8.2.2 Running Casing

The well will be circulated at the anticipated casing point, until sufficent material is on board to run, circulate and cement the casing in place without interruption.

1.8.2.3 Logging

Pipe will be pulled out of hole in order to log until the barite/gel/chemical requirements for drilling as outlined previously have been met.

1.8.2.4 Testing

No testing operation where hydrocarbon flow on surface is anticipated will be commenced, unless weather conditions allow evacuation of the rig personnel to the standby boat.

1.8.2.5 General Rig Operations (Winter Months)

The limiting factor in this regard is the amount of fuel on board. When the supply of fuel is equal to or less than a five day supply at maximum usage, the following procedure will be initiated.

(a) Drilling operations will cease.

(b) Steps will be taken to secure the well.

(c) The drill pipe will be hung off, and preparations made to disconnect.

(d) Prime movers will be shut down as required to conserve fuel.

1.9 Emergency Contingency Plan Procedures

Mobil and ODECO had emergency contingency plans outlining action to be taken in response to various events (eg. blowouts, iceberg approach, etc.). The requirements of the respective contingency plans related to heavy weather are quoted in this section.

1.9.1 ODECO Requirements

1.9.1.1 Severe Storm Measures for all Conditions

(i) Particular attention must be paid to weather forecasts at all times.

(ii) Drill water and salt water may be dumped overboard in the event of severe storm, if necessary, down to a suggested minimum of 28 L.T. salt water retained for fire fighting, engine exhaust cooling and toilets. (1/2 hour)

(iii) Fuel oil may be pumped from deck tanks to lower hull tanks down to the minimum required for essential services and emergency generator. (1 hour)

(iv) All equalizing valves on mud pits are to be closed.

(v) All watertight doors, weather doors and hatches shall be closed. (1 hour)

(vi) The derrick travelling gear shall be lowered to the maximum extent in the guide.
(Time dependent on well operation: 1/2 hour to 8 hours)

Ballasted on Location Only:

(i) After essential pumping has been completed the watertight covers to pump room vents should be closed. All other exposed vents not required for essential services, such as for diesel engines, shall also be closed at the Master's discretion. (2 hours)

(ii) Under exceptionally severe storm conditions, the barge should deballast to an appropriate draft to meet the requirement for Safety Condition. (2 hours)

1.9.1.2 Criteria for Suspension of Drilling

The heavy weather policy is governed by four main criteria:

- Minimize the risk to personnel
- Minimize the storm damage to the vessel
- Minimize storm damage to underwater equipment
- At all times to ensure the security of the well, thus minimizing the possibility of pollution.

There are thee phases to the Heavy Weather policy:

Phase 1 - Stop drilling operations and hang off drill string
Phase 2 - Disconnect the marine riser
Phase 3 - Evacuation of drilling vessel

(a) Phase 1 - Hanging Off

As a general rule, if any of the following criteria are reached, drilling operations will be suspended and the drill string hung off in the well head:

(i) Vessel motions and/or prevailing weather conditions are such that it becomes difficult and/or hazardous to personnel to make connections.

(ii) The significant heave of the rotary table reaches 6 ft. and/or maximum heave reaches 10 ft.

(iii) The maximum angle of the lower ball joint reaches 4 degrees.

(iv) The mean line tension of the highest loaded anchor reaches 75 percent of the test tension.

(b) Phase 2 - Disconnecting

The consequences of disconnecting too late or not at all can be disastrous. On the other hand, disconnecting too early will result in a loss of drilling time. In the long run this loss is not as expensive as the cost for replacing the riser system.

The marine riser should be disconnected from the B.O.P. stack whenever the following criteria are reached, or whenever the Operator Toolpusher or ODECO's Toolpusher has reason to believe they will be reached and/or exceeded in the near future.

(i) The significant heave of the rotary table reaches 8-10 ft., and/or the maximum heave reaches 15 ft. with an expected further deterioration of the weather.

(ii) The maximum angle of the lower ball joint approaches 10 degrees.

(iii) The mean line tension of the highest loaded anchor reaches half of the chain/cable break strength.

Note: In good holding ground the anchors may be able to hold considerably more than the test tension which is limited by the pull available at the winches.

(c) Phase 3 - Evacuation

It should be noted that ODECO's Toolpusher is responsible for any decision to abandon the rig.

For any storm with forecast winds of 100 m.p.h. or more, consider evacuation of personnel and act as follows:

1) Confirm forecast, alert Contractor's Shore Base Manager of environmental condition.

2) Request additional forecast from appropriate Weather Center for rig location at 3 hour intervals.

3) Review the present and past sea conditions to determine if they are rising or falling and to determine what effect the storm is likely to have on the sea conditions.

4) Determine if sea and wind conditions will permit a safe evacuation.

5) Determine if evacuation is necessary or possible.

6) Discuss with Contractor's Shore Manager, and mutually decide if evacuation is necessary or possible.

7) Review procedure for rig evacuation with Barge Master.

8) Prepare rig for total evacuation.

9) Check on availability of tug boats.

10) As conditions warrant

    (i) Evacuate non-essential personnel
    (ii) Evacuate all personnel except skeleton crew
    (iii) Complete evacuation.

The total amount of people in a skeleton crew must not exceed the passenger uplift capacity of either 1 or 2 helicopters. This must be checked with helicopter service, considering the prevailing weather conditions and the distance involved.

Practically, evacuation should not be carried out as long as the rig stays on location. If the anchors are dragging or the anchor chain/cable breaks, then evacuation should be considered.

1.9.1.3 Abandon Platform

(a) Alarm

Alarm indicating a possible Abandon Platform situation is given by continuous sounding of the General Alarm. Locations of General Alarm Buttons are indicated on the Fire Appliance Plan located in the Main Accommodation Passageway.

(b) Abandon Platform Drills

Abandon Platform drill shall be conducted not less than once a week.

All personnel are to respond to Abandon Platform Drills.

The Station Bill indicates where each man shall go and the duties he shall perform. Life Jackets shall be put on.

The Stand-by boat shall be advised and will proceed to the immediate vicinity of the rig prepared to give assistance.

At each drill, one survival craft will be prepared for lowering, the engine started and all systems checked.

At each drill the portable distress transmitter is to be tested and personnel to be instructed in its use.

Personnel are to be instructed in evacuation by helicopter including the use of the helicopter winch hoist and harness.

(c) Life Saving Equipment

Location of appliances is indicated on the Safety Plan.

All personnel will familiarize themselves with the location and operation of Life Saving Equipment.

Barge Captain will ensure that personnel in charge of Survival Craft, Rescue Craft and Liferafts are familiar with the operations of the equipment.

Survival Craft will be lowered in davits and recovered during suitable weather and all systems checked for correct operation at least once in every eight week period.

Access to all Life Saving Equipment shall be kept clear of obstructions at all times.

The Barge Captain will ensure that all personnel lifesaving equipment, lifebelts, flares, rockets and other equipment are in their allocated place and in good condition, within date limits where applicable, at least every eight weeks. Such inspections shall be recorded in OCEAN RANGER's Log Book.

(d) Action in Event of Platform Abandonment

The decision to prepare for platform abandonmment shall be made by OCECO's Toolpusher.

The Abandon Platform Alarm shall be sounded by ODECO's Toolpusher or by a person directly instructed by the Manager to sound the alarm.

All persons will assemble with their life jackets on at appointed stations. Warmest possible clothing should be worn.

The Radio Operator will advise Stand-by Boat and the Air Sea Rescue Services, and such other services as designated in Governmental or Operator instructions, of the possibility of Platform Abandonment, giving Name of Installation, Position, Weather conditions, and reason for planned abandonment.

ODECO's Toolpusher will decide if complete, or partial evacuation leaving skeleton crew, is to be carried out and will advise all parties via the public address system.

In the event of complete abandonment, Assistant Toolpusher will ensure that the well is secured. Rig Mechanic will ensure that all main power plants are shut down and emergency systems are functioning on the batteries. Rig electrician will assist Rig Mechanic, and will ensure obstruction lights are functioning correctly. Control Room Operator will ensure all ballast and sea inlet valves are closed; he will also ensure all watertight doors are closed.

Radio Operator, in the event of complete abandonment will transmit May Day signal and before leaving his post will activate the emergency automatic distress signal transmitter. He will carry the Portable Distress Transmitter with him to his survival craft.

Survival Craft will not be lowered to water until all personnel scheduled for that Craft have been accounted for by Person in Charge.

After evacuation of the rig, survival craft should be driven clear of any hazard and preferably proceed to the Stand-by Boat, or if this is not possible due to prevailing conditions, attempt to remain grouped together as near the location as possible.
If for some reason, a survival craft cannot be used, recourse must be made to the inflatable liferafts. All personnel having to leave the rig should ensure that a liferaft is available in the water, inflated, for them to reach and board.

In the event of evacuation of part of the crew by inflatable liferaft, the other survival craft shall endeavour to collect the inflatable craft and pick up survivors in water wherever they do not risk placing themselves into a dangerous situation.

Stand-by Boat will endeavour to recover survivors and will keep shore based authorities and other vessels in area advised of situations, and will call for assistance as necessary.

1.9.2 Mobil Requirements

1.9.2.1 Weather Contingencies

1.9.2.1.1 Introduction

The following contingencies are only guidelines and that the Drilling Foremen/Rig Toolpushers on site will make the decision on what constitutes a hang-off. One of the contingencies may not necessarily constitute a hang-off in itself; however, it is recommended to initiate the procedure before the majority of the contingencies are met. Consideration should be given to the present drilling operations, the working conditions inherent to the severe weather, and the anticipated intensity of the storm. The weather forecasts as well as the rate of change of the barometer and the rate of change of the intensity of the storm will have some bearing on the decision to hang-off. For instance, if conditions are such that a couple of contingencies are being experienced, but conditions are not intensifying, it may not be necessary to hang-off. 'Pull up and circulate' may be all that is required. However, if only one of the contingencies are being met and conditions are rapidly intensifying, it would be advisable to initiate the hang-off procedure especially if the bit was on bottom and there is several thousand feet to open hole.

1.9.2.1.2 Hang-off Contingencies

(a) Heave: in the range of 8-12 ft. (2.4-3.7m)

(b) Pitch/Roll: in the range of 3-4 degrees

(c) Lateral Offset: approximately 5 percent with respect to the hole positioner

(d) Winds: in the range of 60-70 mph (100-120 kph)

(e) Seas: over 35 ft. (11m)

(f) Anchor Tension: surging up to 75 percent of the maximum tested tension.

1.9.2.1.3 Disconnect Contingencies

(a) Pitch/Roll: in excess of 4 degrees

(b) Lateral Offset: in excess of 6 percent with respect to hole positioner. Experience indicates there are problems disconnecting when the lateral offset is in excess of 4° or 7 percent.

(c) Winds: in excess of 70 mph (110 kph)

(d) Seas: in excess of 40 ft. (12m)

(e) Anchor Tension: surging up to the maximum tested tension.

1.9.2.2 Hang-off and Disconnect Procedures

1.9.2.2.1 Introduction

These guidelines are set up so that the hang-off procedure can be carried out to the point that the only remaining operation necessary in order to disconnect is to push the disconnect button. The disconnect procedure will allow the rig to move off the hole as long as the heave is no greater than 22 ft. (7m) (S.F. = 1.25)*. However, if conditions indicate that a clearance of 13.5 ft. (4m) would not be sufficient, it would be advisable to pull up the telescopic joint and land the outer barrel in the marine riser spider. This will permit a total heave of 45 ft. (13.7m) (S.F. = 1.25).

Since the top of the guide posts are 7.5 ft. (2.3m) above the riser connector, the allowable net heave down is 13.5 ft.(4m). Therefore, the total heave will be 27 ft. (8m). With a safety factor of 1.25, the recommended maximum heave is 22 ft. (7m).

1.9.2.2.2 Hang-off Procedures

(a) Pump mud pill, pull up into casing if time permits. If the bit is up in the casing, consideration should be given to running a back pressure valve. Pick up and run the square shouldered hang-off joint. Space out the hang-off joint in the stack.

(b) Close lower pipe rams. On Cameron preventer, close wedge locks. Land the hang-off tool in the lower pipe rams.

(c) Back off hang-off point. Pull drill pipe out of the hole and check to see that all the running tool has been retrieved. Close blind rams.

(d) Disconnect diverter hydraulic manifold. Remove diverter bag. Install marine riser spider.

(e) Pick up diverter handling tool and make up into diverter assembly.

(f) Tension guide lines to 8000 pounds tension.

1.9.2.2.3 Disconnect Procedures

(a) Reduce the marine riser rucker tension to the calculated weight of the riser.

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* Based on the ruckers pulling the outer barrel up 20 ft. (6m).

(b) Release riser connector and allow the ruckers to lift the riser until the telescopic joint is fully collapsed.

1.9.2.2.4 Land the Marine Riser in the Riser Spider Procedure

(a) Pick up the slip joint with the drawworks, stroke out the inner barrel and pick up the riser to the position that the rucker lines can be disconnected.

(b) Disconnect riser rucker lines and air line to telescopic joint pack off.

(c) Pull up inner barrel with drawworks until the outer barrel can be set in the marine riser spider on the drill floor. Set outer barrel in the riser spider.

(d) Collapse the slip joint and bolt the inner barrel to the outer barrel.

(e) Open the spider beams. Slack off guidelines to 1000 pounds tension.

1.9.2.3 Severe Weather

(a) Pull up into casing. Pick up hang-off joint. Space out hang-off joint in stack.

(b) Close lower pipe rams with 600 psi and land hang-off joint in stack.

(c) Increase pressure on rams to 1500 psi and close wedgelocks.

(d) Back off hang-off joint. Pull drillpipe and close blind shear rams.

(e) Install marine riser spider. Pick up telescopic joint running tool and make up into diverter assembly. Tension guide lines to 800 pound tension.

(f) Release riser connector and allow riser tensioners to lift riser connector for riser connector mandrel. Pick up slip joint with drawworks and take weight off riser and riser connector.

(g) Disconnect choke and kill line hoses from slip joint. Remove work platform from outer barrel of slip joint.

(h) Disconnect riser tensioner lines and bleed pressure from guide line tensioners. Disconnect jumper terminal boxes from hose reels and install running terminal boxes. Make certain that pod messenger line hoists and hydraulic hose reels are manned.

(i) Pull slip joint until outer barrel can be set on marine riser spider. Collapse slip joint and bolt inner barrel to outer barrel. Remove diverter from slip joint and lay down.

(j) Pull slip joint and lay down. Pull one joint of riser and lay it down.

(k) Pick up and re-run slip joint, setting outer barrel on marine riser spider. Pick up diverter assembly and make up on slip joint. Unbolt inner barrel from outer barrel of slip joint and stroke slip joint. Land diverter assembly in riser support housing.

(l) Remove riser running tool from diverter assembly. Open spider beams. Slack off guide lines to 500 pound tension. Lock hydraulic hose reels and secure pod messenger line hoists.

Table 1.1

OCEAN RANGER Data Sheet

Unit Name: OCEAN RANGER
Owner: Ocean Drilling and Exploration Co.
Completion: May, 1976
Class: American Bureau of Shipping AMS A-1 M
Column Stabilized Drilling Unit
Unrestricted operation in floating condition

Vessel Characteristics

Length Overall	398.5 ft.	121.5m
Length Overall (including anchor bolsters)	408.2 ft.	124.4m
Beam	262.0 ft.	79.9m
Beam (including anchor bolsters)	298.4 ft.	91.0m
Height to bottom of upper hull girders	130.0	39.6m
Height to bottom of lower deck	131.5/134.0 ft.	40.1m/40.8m
Height to top of upper deck	151.5 ft.	46.2m
Height to drill floor	175.0 ft.	53.3m
Height to top of derrick	337.0 ft.	102.7m
Maximum operating draft	80.0 ft.	24.4m
Air gap at maximum operating draft	50.0 ft.	15.2m
Minimum operating draft	45.0 ft.	13.7m
Air gap at minimum operating draft	85.0 ft.	25.9m
Maximum transit draft	30.0 ft.	9.1m
Celler deck to drill floor clearance	40.0 ft.	12.2m
Operating water depth with 1650 ft. chain and 5600 ft. wire	1500.0 ft.	457.2m
Lightweight	22,542 Long Tons	
Lightweight VCG	85.0 ft.	25.9m

Capabilities

Bulk Storage Capacity		
(Columns)	13,275 ft^3	375.9M^3
(Deck)	8,780 ft^3	248.6M^3
(Total)	22,055 ft^3	644.5M^3
Liquid Mud Capacity		
(Main Pits)	2,000 Bbls.	317.7M^3
(Mud Return Pits)	450 Bbls.	71.5M^3
Sack Storage Capacity	20,000 sacks	
Fuel Oil		
Lower Hulls	20,400 Bbls.	3240.7M^3
Upper Deck	50,200 Gal.	190.0M^3
Drill Water		
Lower Hulls	19,400 Bbls.	3081.8M^3
Upper Deck	26,000 Gal.	98.4M^3
Portable Water (Upper Deck)	48,000 Gal.	184.7M^3
Lube Oil (Upper Deck)	5,000 Gal.	18.9M^3
Pipe Rack	21,400 ft^2	1988.1M^2
Quarters	99 beds (+ 6 hospital beds)	

Table 1.1 OCEAN RANGER Data Sheet (Continued)

Equipment

Derrick:	Lee C. Moore	160 x 40 x 40 ft.	1,300,000 lb.
Compensator:	Rucker	18 ft.	400,000 lb.
Cranes:	2 National 1 Link Belt		80 ton 60 ton
Drawworks:	Continental - Emsco C-3 Type 2, 4 speed		3,000 hp
Rotary:	Oilwell	49.5 in.	1,000 hp
Mudpumps:	2 Continental - Emsco FA-1600 triplex		1,600 hp each
BOP Stack:		13.6 in.	5,000 psi 10,000 psi
Engines:	4 Fairbanks-Morse 12 cyl. 38 TD8-1/8 turbo charged 1 Fairbanks-Morse 10 cyl. 38 D8-1/8		3,600 hp each 1,800 hp
Electrical Generators	8 2 1	1,600 kW DC 1,400 kW AC 1,200 kW AC	
Propulsion:	4 electric motors powering twin screws (Kort Nozzels)		14,000 hp total
Mooring:	12 anchors Combination 5,600 ft. 3.5 in. wire rope and 1,650 ft. 3.75 in. chain	45,000 lb. each	
Positioning:	12 Winch Windlass units		

Table 1.2

Communications Equipment Onboard the MV OCEAN RANGER

A. Ships Radio Systems

1. ITT MRU 29B main and reserve transmitters, receivers, auto alarm receiver, auto alarm keyer, antenna switch, power supplies, battery charger and batteries.

2. VHF marine radios:

   (a) Decca, ITT STR - 24
   (b) Motorola, D33ADA1019AK

3. EPIBR - AKC Electronics, AKC/RLB 14

B. H.F. Radio Systems

1. Communications Associated, Inc., Model CA35MS with CL36 amplifier, frequency range: 2-30 MHZ. Power output: 1,000 watts.

2. Communications Associates, Inc. model CA 35MS. Frequency: 2-30 MHZ. Power output: 100 watts. Two-tone alarm: Honeywell TG502. Power: Battery or ships power.

3. R.F. Harris Co. Model RF230MAC. Frequency: 2-30 MHZ. Power output: 100 watts.

C. Miscellaneous Communications Systems

1. CAI model CR19/C754 VHF aircraft radio. Frequency: 122.00 MHZ. Power: 50 watts. Emission: A3A.

2. Scientific Atlanta MARISAT Terminal.

3. Souther Avionics Aircraft Beacon, Model SS800.

Table 1.3
Work History

DATES	LOCATION	OPERATOR
May, 1976	No. 2 Eba Shipyard of Mitsubishi Heavy Industries, Japan	Launching
6/3/76–6/26/76	Tow from MHI shipyard in Japan to Alaska	ARCO
6/26/76–10/01/76	Cost No. 1, St. George Basin, Alaska	ARCO
10/1/76–10/15/76	Tow from Bering Sea to Gulf of Alaska	ARCO
10/15/76–6/3/77	Splome No. 1, Blk. 72- Gulf of Alaska	ARCO
6/3/77–6/9/77	Tow from Gulf of Alaska to Lower Cook Inlet	ARCO
6/9/77–9/27/77	Lower Cook Inlet, Cost No. 1	ARCO
9/27/77–3/12/78	Stand by – Lower Cook Inlet	IDLE
3/12/78–3/15/78	Tow from Lower Cook Inlet to Resurrection Bay	IDLE
3/15/78–12/4/78	Stand by – Seaward Resurrection Bay	IDLE
12/4/78–12/14/78	Tow from Resurrection Bay to Port Alberni, B.C.	IDLE
12/14/78–8/5/79	Stand By – Port Alberni Harbour, B.C.	IDLE
8/5/79–12/16/79	Tow from Port Alberni, B.C. to Baltimore Canyon via Straits of Magellan and Naragansett Bay	–
12/16/79–5/29/80	Baltimore Canyon, Blk. 106	Murphy
5/29/80–6/17/80	Tow from Baltimore Canyon to Ireland	Phillips
6/17/80–10/20/80	Offshore Ireland	Phillips
10/20/80–11/06/80	Tow from Ireland to Newfoundland	Mobil
11/06/80–2/24/81	G-55 Hibernia, Newfoundland	Mobil
2/24/81–6/7/81	K-18 Hibernia, Newfoundland	Mobil
6/7/81–11/24/81	J-87 Sheridan, Newfoundland	Mobil
11/24/81–2/15/82	J-34 Hibernia, Newfoundland	Mobil

Table 1.4

SUMMARY OF OCEAN RANGER DAILY LOGS from JUNE 1976 TO FEBRUARY 1982 WHEN SIGNIFICANT STORMS OCCURRED

Date	Location	Draft (ft)	Max Wave Height (ft)	Max Heave (ft)	Max Wind Speed (mph)	Comments	GMD (ft)	GML (ft)	Swell (ft)	Max Roll	Max Pitch	Rig Dir	Wind Dir
						(...see notes below...)				(......Degrees......)			
16OCT76	Gulf of Alaska	55	16-20	N/A	65-72	W.O.W.	22.25	29.95	18-20	3.2	2.0	320	ENE
17OCT76	" "	77	8-10	N/A	86	W.A.D.	7.29	4.39	18	2.0	1.5	338	ENE
28OCT76	" "	80	7-8	1	45-50	W.A.D.	5.90	4.57	15-18	0.5	0.5	333	ENE
29OCT76	" "	80	4	1-2	25-55	W.A.D.	6.01	4.65	7-8	1.0	1.0	333	ENE
30OCT76	" "	80	10-12	7-8	45-55	W.A.D.	5.54	4.02	25	1.5	2.5	333	ENE
01NOV76	" "	80	5	1-2	51	W.A.D.	6.53	5.03	6	0.5	0.5	333	ENE
02NOV76	" "	80	10-12	4-5	65	W.O.W.	6.56	5.06	10-12	1.0	1.0	333	ENE
06NOV76	" "	80	9-10	5	67	W.O.W.	6.14	4.69	9-10	1.0	1.2	333	ENE
09NOV76	" "	80	8-9	3-4	59	W.O.W.	6.22	4.76	10-12	1.0	1.5	333	ENE
14NOV76	" "	80	8-9	4	39	W.A.D.	5.63	4.21	10-12	1.5	1.2	333	ENE
15NOV76	" "	80	8	10	67	W.O.W.	5.78	4.38	10-12	1.5	1.2	333	E
14DEC76	" "	78.5	10	8.7	74	W.A.D.	3.87	2.36	22	3.7	1.9	332	ENE
15DEC76	" "	78	10	9.9	82	W.A.D.	2.77	2.26	28	2.5	4.2	332	ENE
19DEC76	" "	78	16	6	66	W.A.D.	3.50	2.00	18	1.5	1.5	332	SE
20DEC76	" "	77	8	5	29	W.A.D.	3.50	2.00	8-10	1.5	0.5	332	E
21DEC76	" "	77	8	5	75	W.A.D.	4.45	2.90	12-14	1.5	1.5	332	ENE
04JAN77	" "	77	9	5	75	W.A.D.	----	2.84	14	2.0	2.0	332	E
05JAN77	" "	77	8	4	60	W.A.D.	----	1.78	12	1.0	1.0	332	E
05JAN80	Baltimore Canyon	78	8-10	6-10	45-50	W.A.D.	5.60	3.60	26-30	4.3	5.1	225	N
06JAN80	"	78	6-8	5-6	40-45	W.O.W.	4.58	2.58	18-24	2.9	4.0	225	N
07JAN80	"	78	10-12	4-6	40-50	W.A.D.	6.50	4.50	8-12	2.1	3.5	225	WSW
08FEB80	"	78	12-16	8-14	28-35	W.A.D.	4.01	2.01	8-10	3.0	3.5	225	NW
28FEB80	"	78	7	1-2	38-40	W.A.D.	4.90	2.90	9-11	3.6	3.5	225	WNW
14MAR80	"	78	8-10	12	35-45	W.A.D.	5.38	3.38	10-15	3.3	3.1	225	W
23MAR80	"	78	6-10	8-14	30	W.A.D.	5.31	3.31	6-10	1.3	2.2	225	NW
11SEP80	Ireland	78	5	15	50	W.A.D.	5.13	3.13	30	4.5	3.0	187	WNW
12SEP80	"	78	16	9.5	60	W.A.D.	5.16	3.16	30	5.0	2.5	187	WNW
15SEP80	"	---	4	4.3	58	W.O.W	4.87	2.87	12	2.5	1.5	187	NW
07OCT80	"	78	14	14.8	80	W.O.W.	3.80	1.80	11	5.7	5.0	187	NW
08OCT80	"	78	40	18.4	75	W.O.W.	5.78	3.78	11	7.0	3.5	187	NW
19NOV80	Newfoundland	78	6-8	8.1	47-55	W.A.D.	6.29	4.29	10-12	2.6	3.2	230	E
20NOV80	"	78	8	5.8	68	W.A.D.	6.07	4.07	18	4.3	5.2	230	WNW

SUMMARY OF OCEAN RANGER DAILY LOGS from JUNE 1976 TO FEBRUARY 1982 WHEN SIGNIFICANT STORMS OCCURRED Cont'd

Date	Location	Draft (ft)	Max Wave Height (ft)	Max Heave (ft)	Max Wind Speed (mph)	Comments	GMD (ft)	GML (ft)	Swell (ft)	Max Roll	Max Pitch	Rig Dir	Wind Dir
						(...see note below...)				(......Degrees......)			
21NOV80	Newfoundland	78	8-12	12.7	30	W.O.W.	5.71	3.71	18-20	4.3	5.2	230	WNW
19JAN81	"	80	12	4.5	72	W.A.D.	3.53	1.70	10	2.3	1.3	230	SE
20JAN81	"	80	20	8.5	47	W.A.D.	3.47	1.64	10	3.9	3.6	230	SW
21JAN81	"	80	14	4.5	29	W.A.D.	3.72	1.70	--	1.7	2.4	230	WSW
27SEP81	"	80	23	16	60	W.A.D.	3.75	2.00	—	2.1	3.2	310	WNW
28SEP81	"	80	15	15	40	W.O.W.	4.01	2.48	—	1.5	1.8	310	WNW
29SEP81	"	80	10	6	30	W.A.D.	4.01	2.50	8	0.8	0.8	310	SE
09NOV81	"	80	18	10	45	W.A.D.	3.51	1.73	15	3.4	1.8	310	SE
27DEC81	"	80	18	14	55	W.A.D.	3.90	2.13	16	1.8	2.8	311	WNW
31DEC81	"	80	25	9	60	W.A.D.	3.74	2.02	10	2.5	2.1	311	WSW
02JAN82	"	80	21	13	32	W.A.D.	2.53	1.50	18	1.6	1.5	311	N
15JAN82	"	80	20-34	5-8	55-65	W.A.D.	3.01	1.98	13-17	1.2-3.4	1.0-4.0	311	SSW
16JAN82	"	80	28-47	16-22	60-80	W.O.W.	2.99	1.96	20-25	2.3-5.5	2.0-4.5	311	WSW
17JAN82	"	80	18-39	8-15	50-60	W.A.D.	3.20	2.17	15	1.5-3.0	3.5	311	SE
18JAN82	"	80	18-39	8-18	50-60	W.O.W.	3.26	2.23	10	1.5-4.5	1.5-4.5	311	WSW
19JAN82	"	80	22-36	8-15	45-55	W.O.W.	3.09	2.06	—	1.1-4.0	1.1-3.5	311	WxS
20JAN82	"	80	18-30	6-12	53-64	W.A.D.	2.94	1.91	—	1.0-4.0	1.0-3.5	311	WxS
22JAN82	"	80	15	4-8	29	W.A.D.	2.96	1.93	14	1.0-1.8	1.5-2.5	311	W
*14FEB82	"	80	32-34	3-5	72	W.A.D.	5.00	2.04	10	2.0-3.0	1.4	311	W *

* For period ending 1600 on 14 February 1982.

Notes: W.O.W. - Waiting on Weather
W.A.D. - Working as Directed
GMD - Diagonal Metacentric height
GML - Longitudinal metacentric height

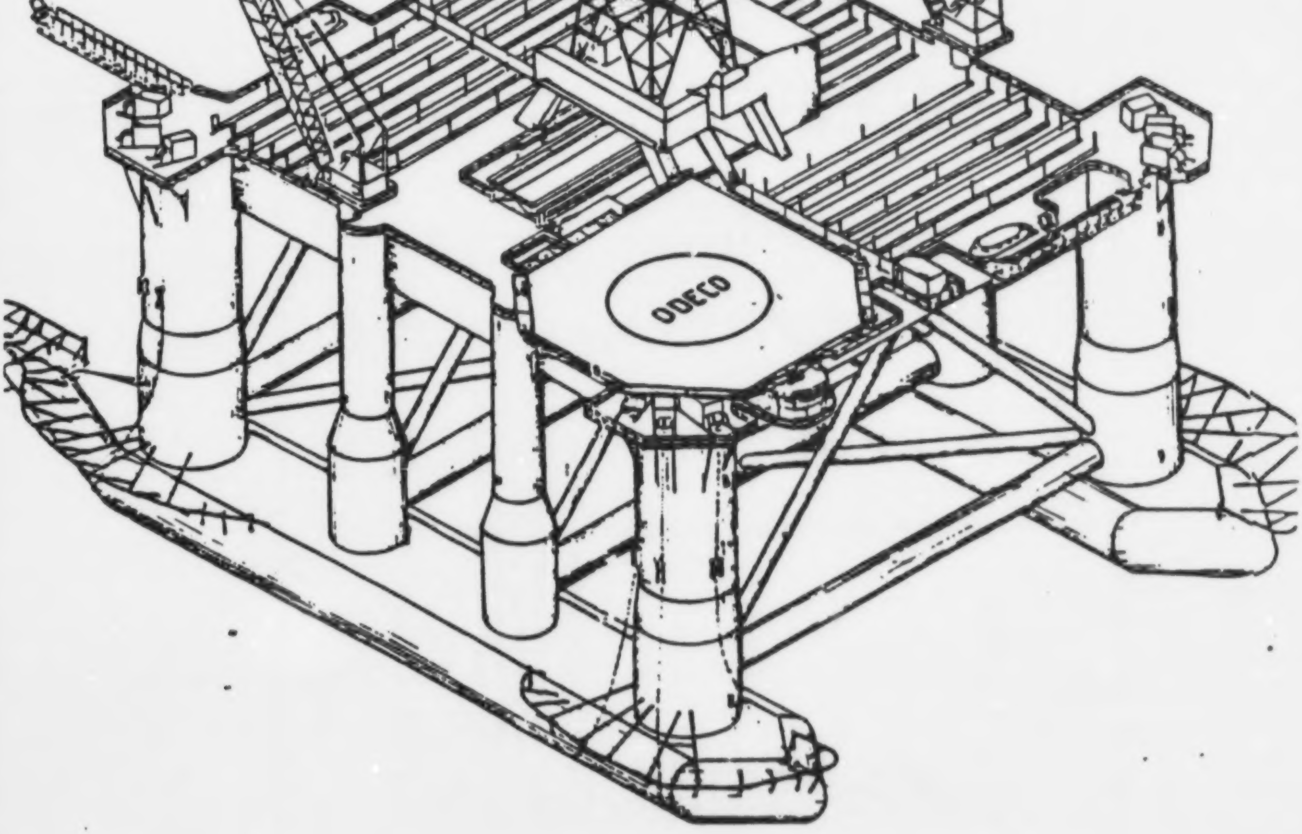


Figure 1.1 OCEAN RANGER Isometric View

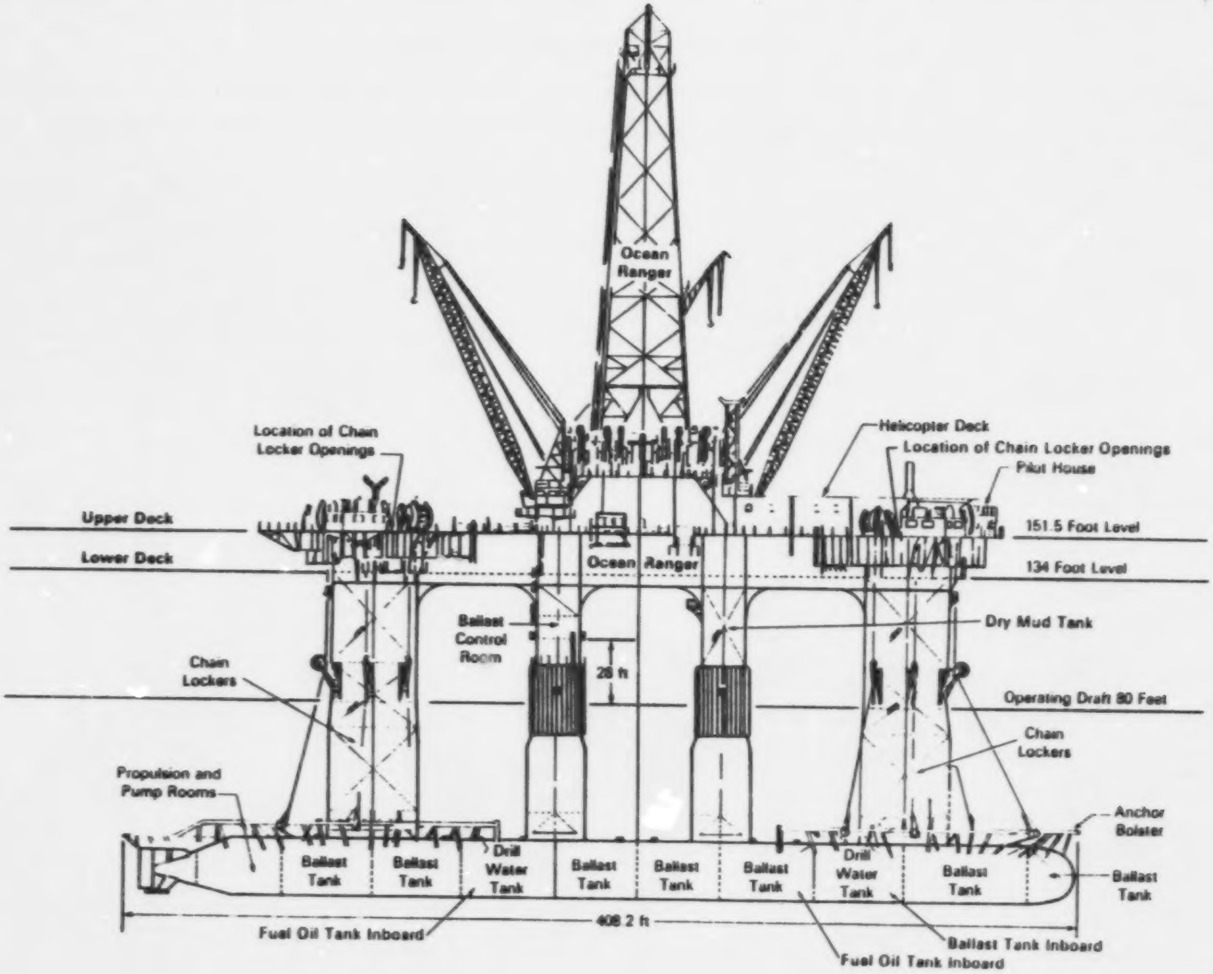

Ocean Ranger
Location of Chain Locker Openings
Helicopter Deck
Location of Chain Locker Openings
Pilot House
Upper Deck
Lower Deck
Ocean Ranger
151.5 Foot Level
134 Foot Level
Ballast Control Room
Dry Mud Tank
28 ft
Chain Lockers
Operating Draft 80 Feet
Chain Lockers
Propulsion and Pump Rooms
Anchor Bolster
Ballast Tank
Ballast Tank
Drill Water Tank
Ballast Tank
Ballast Tank
Ballast Tank
Drill Water Tank
Ballast Tank
Ballast Tank
408.2 ft
Fuel Oil Tank Inboard
Ballast Tank Inboard
Fuel Oil Tank Inboard

Figure 1.2 Starboard Elevation

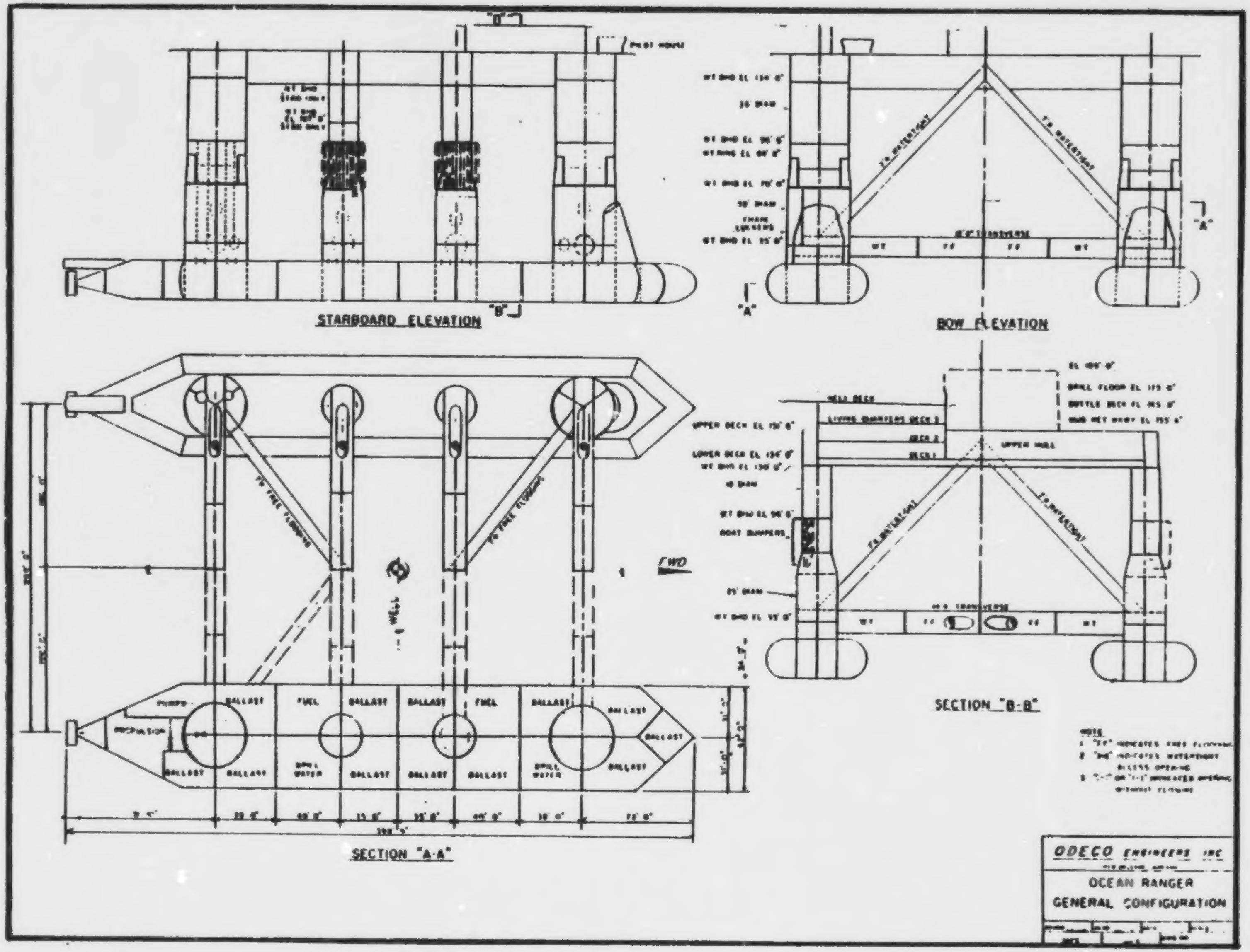

STARBOARD ELEVATION
PILOT HOUSE
WT BHD
"B"
"D"
BOW ELEVATION
WT BHD EL 134' 0"
35' DIAM
WT BHD EL 90' 0"
WT RING EL 88' 0"
WT BHD EL 70' 0"
38' DIAM
CHAIN LOCKERS
WT BHD EL 35' 0"
"A"
TO WATERTIGHT
WT
FF
SECTION "A-A"
PUMPS
PROPULSION
BALLAST
FUEL
DRILL WATER
WELL
FWD
TO FREE FLOODING
23' 0"
40' 0"
15' 0"
44' 0"
38' 0"
73' 0"
SECTION "B-B"
EL 189' 0"
DRILL FLOOR EL 173' 0"
BOTTLE DECK EL 165' 0"
MUD NET WORK EL 155' 0"
HELI DECK
LIVING QUARTERS DECK 3
DECK 2
DECK 1
UPPER HULL
UPPER DECK EL 151' 0"
LOWER DECK EL 136' 0"
WT BHD EL 130' 0"
WT BHD EL 96' 0"
BOAT BUMPERS
25' DIAM
WT BHD EL 35' 0"
NOTE
1 "FF" INDICATES FREE FLOODING
2 INDICATES WATERTIGHT ACCESS OPENING
3 INDICATES OPENING WITHOUT CLOSURE
ODECO ENGINEERS INC
OCEAN RANGER
GENERAL CONFIGURATION

Figure 1.3 General Configuration

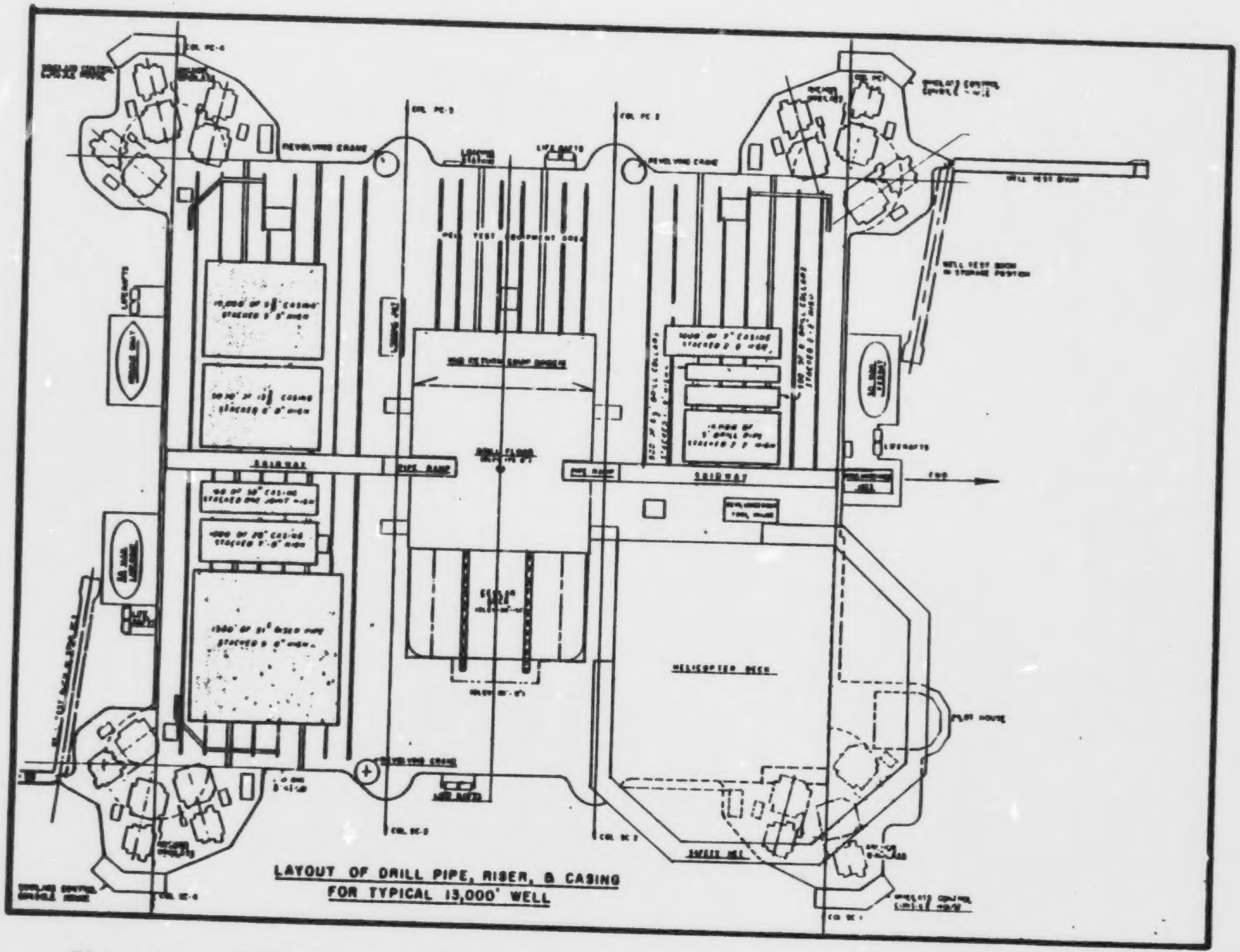

COL. PC-4
COL. PC-3
COL. PC 2
COL. PC 1
REVOLVING CRANE
REVOLVING CRANE
LIFERAFTS
WELL TEST EQUIPMENT AREA
WELL TEST BOOM
WELL TEST BOOM IN STORAGE POSITION
LIFERAFTS
LIFERAFTS
SKIDWAY
PIPE RAMP
DRILL FLOOR
PIPE RAMP
SKIDWAY
FWD
TOOL HOUSE
HELICOPTER DECK
PILOT HOUSE
REVOLVING CRANE
LIFE RAFTS
COL. SC-4
COL. SC-3
COL. SC 2
COL. SC 1
LAYOUT OF DRILL PIPE, RISER, & CASING
FOR TYPICAL 13,000' WELL

Figure 1.4 OCEAN RANGER General Arrangement, Upper Deck

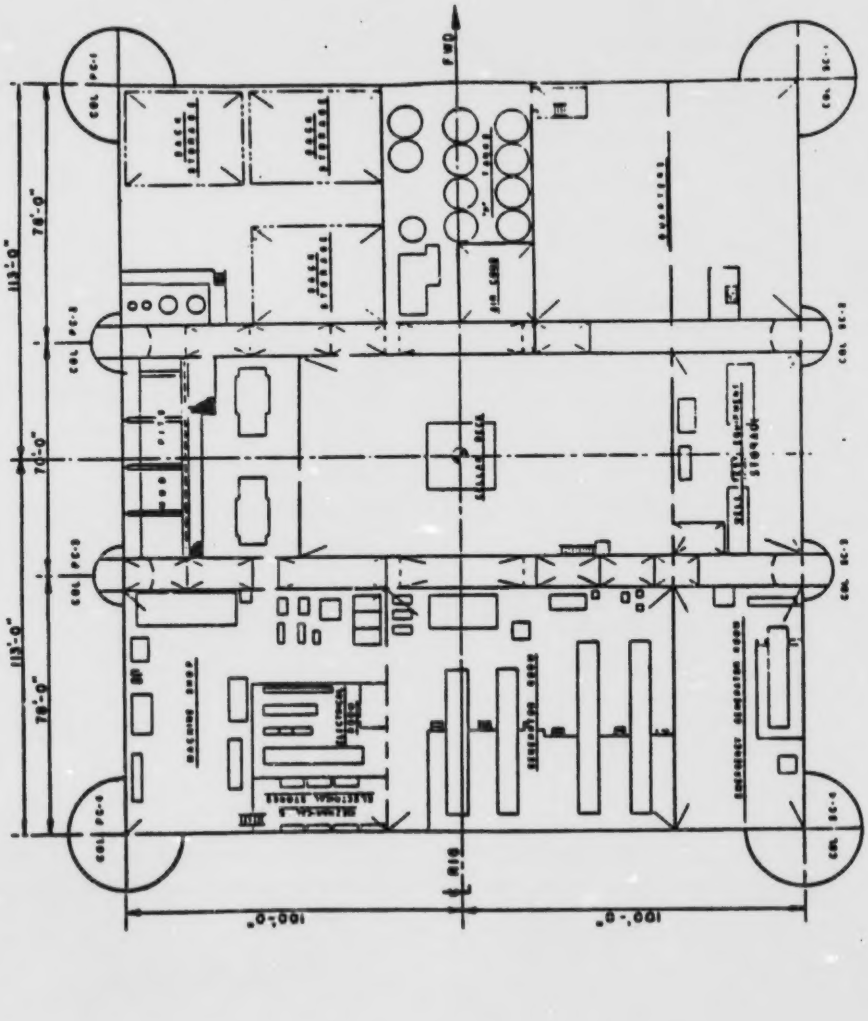

FWD
113'-0"
78'-0"
70'-0"
113'-0"
78'-0"
100'-0"
100'-0"

Figure 1.5 OCEAN RANGER General Arrangement; Lower Deck

CHAPTER 2 STABILITY

2.1 General

The OCEAN RANGER was designed to meet the requirements of the American Bureau of Shipping "Rules for Building and Classing Offshore Mobile Drilling Units - 1973", as a Column Stabilized Drilling Unit. The unit was designed to have positive metacentric height in calm water equilibrium position for all afloat conditions including temporary positions when ballasting or deballasting.

2.2 OCEAN RANGER Stability Requirements

2.2.1 Requirements according to ABS Rules

A brief description of the rules, as applicable, is given:

(1) All units must have positive stability in calm water equilibrium position, for the full range of drafts.

(2a) Operating Condition: All units are to have sufficient stability (righting ability) to withstand the overturning effect of the force produced by a steady wind from any horizontal direction of not less than 36 metres/sec (70 knots) for all operating conditions.

(2b) Safety Conditions: The capability is to be provided to change the mode of operation of the unit to that corresponding to a severe storm condition with steady wind velocities of not less than 51.5 metres/sec (100 knots), in a reasonable period of time.

For items (2a) and (2b) the area under the righting moment curve should be at least 1.3 times the area under the wind moment curve.

(3) All units are to have sufficient stability to withstand the flooding from the sea of any one main compartment which may reasonably be expected to be flooded for any operating condition (which has been reviewed under 2a or 2b). The unit is to possess sufficient reserve stability to withstand the additional overturning moment of a 25.8 metres/sec (50 knots) wind superimposed from any direction.

In this condition, the final waterline is to be below the lower edge of any opening through which downflooding may take place.

(4) Righting moment curve is to be positive over the entire range of angles from upright to second intercept.

2.2.2 Owner's Requirement

In addition to the foregoing, the unit was designed to have at least 1.5 ft. positive metacentric height in all directions, after correction of KG (height of centre of gravity above keel) for free surface, in all Operating and Safety Conditions.

2.2.3 Vessel Characteristics

A set of typical righting and wind heeling moment curves is shown in Figure 2.1 The allowable KG_L for various drafts as given in the operations booklet is shown in Figure 2.2 (bold lines). Damage of two adjacent compartments in the waterline regions of the columns was assumed. The subsections of 2.2.1 that limit the KG in different draft ranges are indicated in circles. The limitation due to 2.2.2 is shown by a dotted line.

In the present study the righting and wind moment curves were calculated based on available OCEAN RANGER drawings (Appendix 1). The allowable KG values, (Figure 2.2 - lighter lines) as calculated above are lower than those shown in the operations booklet. This could have caused the operator to carry a larger deck load than is allowed by the ABS rules, making the unit more sensitive to external overturning forces and shifting weights.

2.2.4 Accepted Modes of Operation

The criteria for the relevant modes of operation at 80 ft., 75 ft. and 58 ft. drafts are given in Section 1.8.1.2.

2.3 Ballast Configuration

2.3.1 Ballasting or Deballasting Procedure

It is necessary to ballast the barge in such a manner that:

(a) An approximately level keel is maintained throughout

(b) Structural stresses are minimized during the process

(c) Loading and free surface is restricted to certain tanks, at all times

(d) Not less than 400 LT, and preferably more, is placed in each of port and starboard tanks WB 2 and WB 3 at operating draft in order to limit the immersion of the barge in case any of these four large tanks is accidentally damaged and becomes completely flooded.

(e) KG of unit does not exceed the allowable KG in any condition

2.3.2 Ballast Configuration

The recommended amount of fluids in the lower hull tanks under normal operating conditions is shown in Figure 2.3. Water ballast tanks 8 and 9 are left dry to mimimize stresses and to eliminate free surface ((b) and (c) of 2.3.1).

The recommended ballast distribution indicates full or nearly full tanks towards the aft end with the centre tanks mostly empty. A more even distribution of ballast and greater tank capacity aft would have increased the unit's ability to counterflood aft if needed.

Based on stability work sheets obtained from the diving survey after the accident (Appendix 2) the amount of fluids in the lower hull tanks are shown in Figure 2.4. Ballast tanks 8 and 9 are full contrary to recommendation 2.3.1.(b). The amount of fluids in the lower hull tanks after capsize is given in Appendix 2.

2.4 Stability Analyses

The OCEAN RANGER, on the night of the accident, developed a port bow list, capsized, and sank. There had been problems with the ballast control panel prior to the accident. Various analyses were performed to study the results of transfer of ballast and flooding of ballast tanks and chain lockers. The scope of the studies were:

(1) Static stability analysis to determine the sensitivity of the rig to wind, mooring, ballast transfer and flooding (Appendices 1 and 3).

(2) The effect of the seaway related to flooding of the chain locker, neglecting dynamic effects (Appendix 4)

(3) The effect of the seaway related to flooding of the chain locker, including dynamic effects ("OCEAN RANGER Chain Locker Flooding in Severe Waves", David W. Taylor Naval Ship Research and Development Center).

2.4.1 Chain Lockers

The upper deck is 151.5 ft. (46.2 m) above the bottom of the lower hull. Water can enter the chain locker through three chain pipes and three openings for the wire at each corner column. The openings for the wire (each 25 ft^2/2.3m^2) were inboard of the chain pipe (6 ft.^{2}/0.56 m^2). For a draft of 80 ft. the angle of heel for downflooding in a still water condition is given in Table 2.1 (Appendix 1).

2.4.2 Static Stability Analysis

The diving survey indicated the amount of fluids in the ballast tanks. Changing the pressure of trapped air from hydrostatic to atmospheric and comparision with the fluids in the tanks on February 14, 1982 indicated an inflow of 1935 LT. Port and starboard WB 1 tanks were damaged and were full after capsize (Appendix 2). The extent of the damage is such that rupture of the shell could have resulted with ingress of water of about 1000 LT, into the WB 1 tanks. Also, damage to port WB 2 would result in an ingress of about 300 LT.

During capsize there may have been some transfer of fluids but, provided the tanks and the piping remained intact, subsequent significant transfer is unlikely (Appendix 1). This would suggest that the difference in the ballast configuration before and after capsize (Figure 2.4) should have occurred prior to capsize.

The moorings provide restraint against inclining of the rig and could be represented as a reduction in KG. The effect of mooring on inclination of the rig is shown in Table 2.2.

However, in determining the above values, no slackening of leeward lines was assumed, which would reduce the restraint offered by the moorings. Considering the possibility that some slackening of leeward lines had occurred a net reduction of 1.5 ft. for the effect of moorings is assumed in the analysis. A previous report on static stability (Appendix 3) indicated

(1) Under pure trim, transfer of ballast in the port and starboard hulls, starting with the ballast configuration on February 14, 1982, from the after-most tanks to the forward-most tanks would immerse the upper hull

(2) Transfer of ballast from the after-most tanks to the forward-most tanks in the port hull, starting with the ballast configuration on February 14, 1982, and flooding the port forward chain lockers by less than 50 percent would immerse the upper hull

(3) Assuming that the upper hull is not watertight and would provide no buoyancy, capsize for the above two conditions is possible even in a still water condition.

The above study was based on the assumption that listing occurs about the centreline: however, this does not satisfy equilibrium constraints. Similar calculations were done ensuring equilibrium in the listed configuration. Equilibrium positions were obtained for the following:

(1) Flooding port tanks WB 1, WB 2 and WB 4,

(2) Transfer of ballast from port tank WB 16 to port WB 1,

(3) Transfer of ballast from port tanks WB 16 and WB 15 to port tanks WB 1, WB 2 and WB 4,

(4) Flooding port forward chain locker for the above cases (1), (2) and (3),

(5) Flooding forward port and starboard chain lockers for cases (1), (2), and (3).

These calculations were based on the assumption that the upper hull remains buoyant. As the vertical centre of gravity of the rig at the time of the accident is not known exactly, computations were made for three values of KG, 61, 63 and 65 feet (including free surface correction) from a draft of 80 ft. The upper hull was submerged significantly for case (5); hence and if the buoyancy of the upper deck were lost due to flooding, the inclination of the rig would progressively increase and the rig would capsize.

The control switches for the port hull on the ballast control panel were closest to one of the windows that were found broken during the diving survey. Based on a review of ballast configurations before and after the accident and assuming minimum malfunction of valves, equilibrium positions were determined due to transfer of ballast from port tank WB 10 to either port tank W1 2 or WB 4. (Appendix 1)

Prior to the accident port tank WB 10 was full while port tanks WB 1 and WB 4 were nearly empty. The diving survey found port tanks WB 1 and WB 4 full. All ballast tanks are connected to a common manifold, with one remotely operated valve (ROV) for each tank. Flow between two tanks is possible with the respective ROV's for the two tanks in an open position.

Opening ROV's for port tanks WB 10 and WB 4 or WB 1 would cause water transfer from port tank WB 10 to WB 4 or WB 1 until the inclined water surface reached the ballast pipe bell mouth in WB 10 for transfer to WB 4 or the levels in WB 10 and WB 1 equalize for transfer to WB 1. This transfer of ballast would cause a forward trim of 11° for a transfer from port WB 10 to port WB 4 and 11.8° for a transfer to WB 1 (Appendix 1). This reduces the freeboard to the most forward chain pipe from 71.5 ft. to 44 ft. for transfer to port WB 4 and to 42 ft. for transfer to port WB 1 without taking waves into account. The time for transfer from port tank WB 10 to WB 4 was calculated to be about 2 hours (Appendices 1 and 5).

2.4.3. The Effect of Waves

2.4.3.1 Neglecting Dynamic Effects

The time required to immerse the upper hull with the OCEAN RANGER heeled about the 45° axis (port bow down) at various angles for different significant wave heights (the average of one-third highest waves) were studied (Appendix 4). A Rayleigh distribution was assumed for wave heights with six wave groups for the one-third highest waves. The motions of the unit (heave, pitch and roll) were neglected. It was assumed that a particular wave crest had to be two feet above the opening to cause chain locker flooding. For higher waves a constant flooding of 5 tons was assumed for each passage of the wave. The additional list due to this flooding was calculated including the righting effect of the moorings (Appendix 3). The analysis indicated that:

(i) For a draft of 80 ft and a 35 ft significant wave height chain locker flooding would take place at a list of 14.5°. It would take three and a half hours with an initial list of 15° to immerse the upper hull and one and a half hours with an initial list of 15.5°.

(ii) For a draft of 85 ft. and a 35 ft. significant wave height chain locker flooding would take place at a list of 13°. It would take two and a half hours with an initial list of 13.5° to immerse the upper hull and one and a half hours with an initial list of 14°.

The angles of list for downflooding and flooding times would decrease with adverse motion of the unit, wave rideup and larger downflooding for higher waves. The values would increase for motions of the unit along with the waves.

2.4.3.2 Including Dynamic Effects

The time required to immerse the upper hull by chain locker flooding for various list angles, taking into account the motions of the unit (pitch, heave, roll) was studied.* The effect of mooring forces were neglected as the motions of the unit were similar with mooring forces included. Listing about a 45° axis was assumed. The relative position of the wave crest to downflooding points was computed. The chain locker flooding rate was based on the profile of the wave over the opening and the time the wave is over the opening. The results indicated that:

(i) For a draft of 80 ft. and a list of 15° a wave height of 125 ft is required to cause downflooding

(ii) For a draft of 80 ft. and a list of 24.4° the time to fill chain locker was 7.5 min for a significant wave height of 36.7 ft.

The computations were based on regular wave theory, giving higher motions of the unit. In irregular waves the angle of heel for chain locker flooding would be reduced. The time for filling the chain locker is based on a constant wave height; a Rayleigh distribution for wave heights would reduce the time for downflooding.

---

* "OCEAN RANGER Chain Locker Flooding in Severe Waves", David W. Taylor Ship Research and Development Center.

Table 2.1

Angle of Heel (ϕ) For Downflooding to Chain Lockers, For Different Heeling Axis (ω)

Draft = 80 feet (24.4m)

ω	ϕ	ω	ϕ
0	28.1	195	24.2
15	24.0	210	22.0
30	21.9	225	21.3
45	21.2	240	21.7
60	21.7	255	23.0
75	22.9	270	25.7
90	25.6	285	23.4
105	23.3	300	21.9
120	21.8	315	21.3
135	21.2	330	22.0
150	21.9	345	24.2
165	24.0		
180	28.1		

Table 2.2

Effect of Mooring

Inclination (deg)	Moment (1000 Lt ft.)	Virtual Reduction of KG (ft.)
10	23	3.2
20	53	4.0
30	123	6.3
40	245	9.8

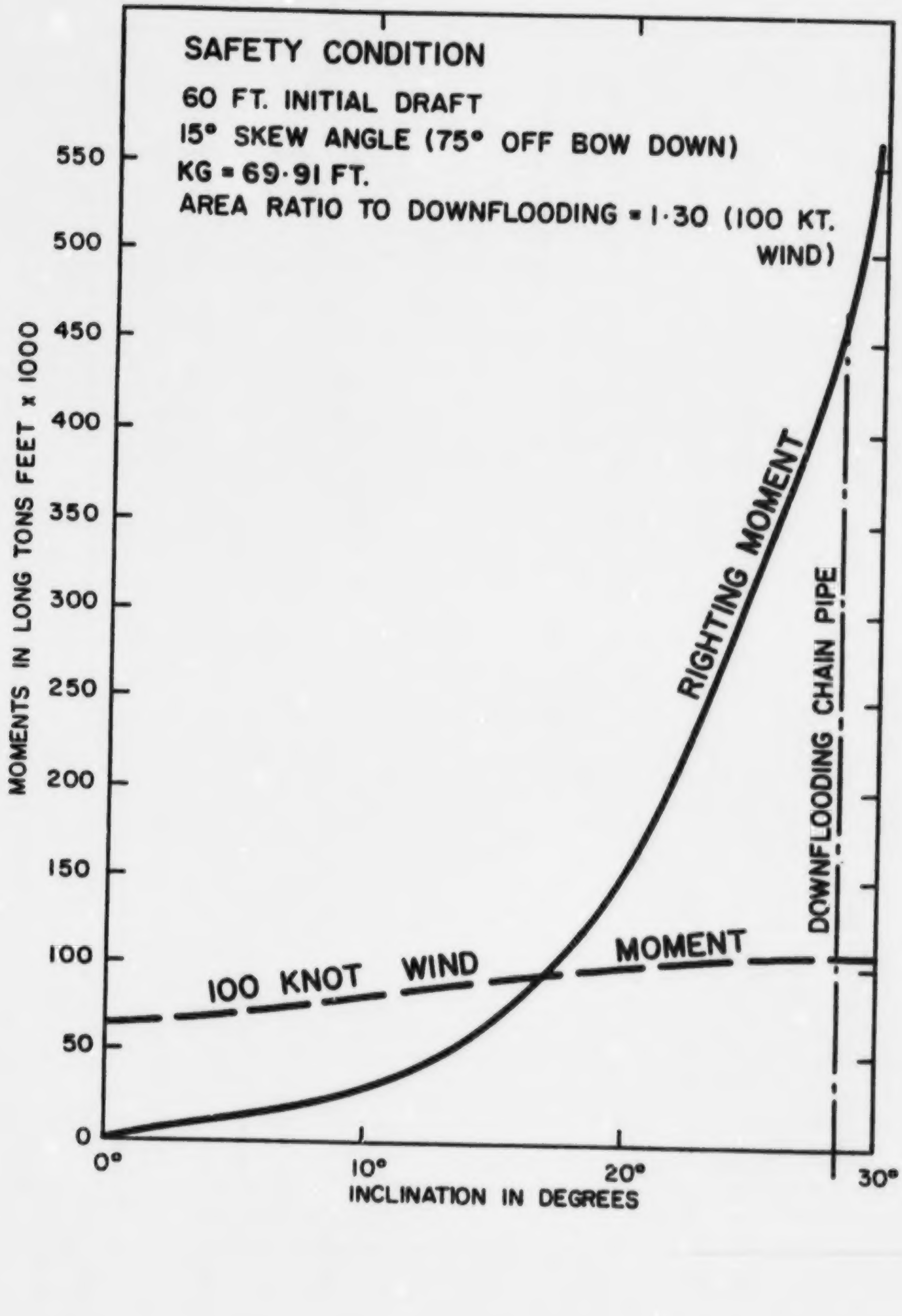


Figure 2.1 Righting and Wind Heeling Moments

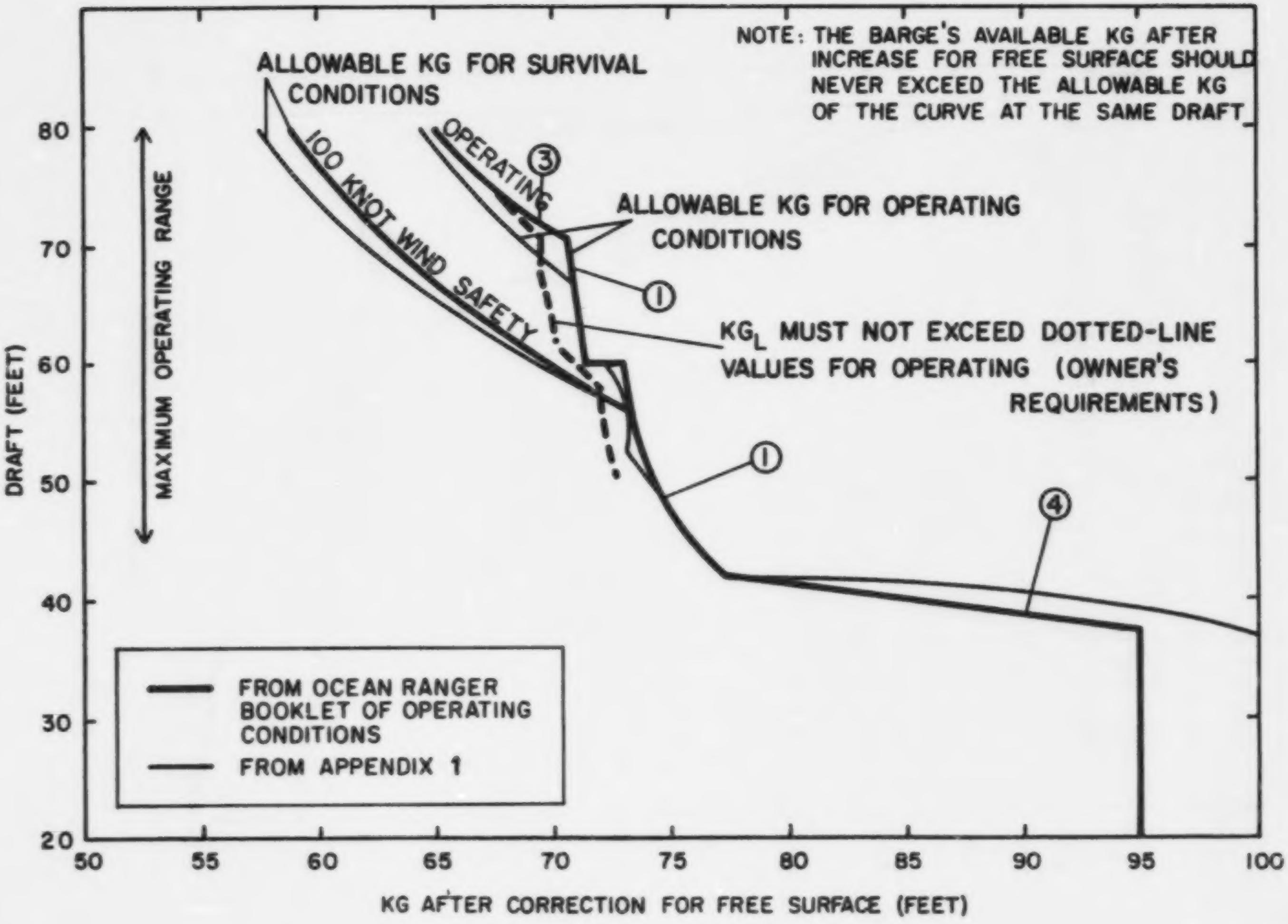


Figure 2.2 Allowable KG

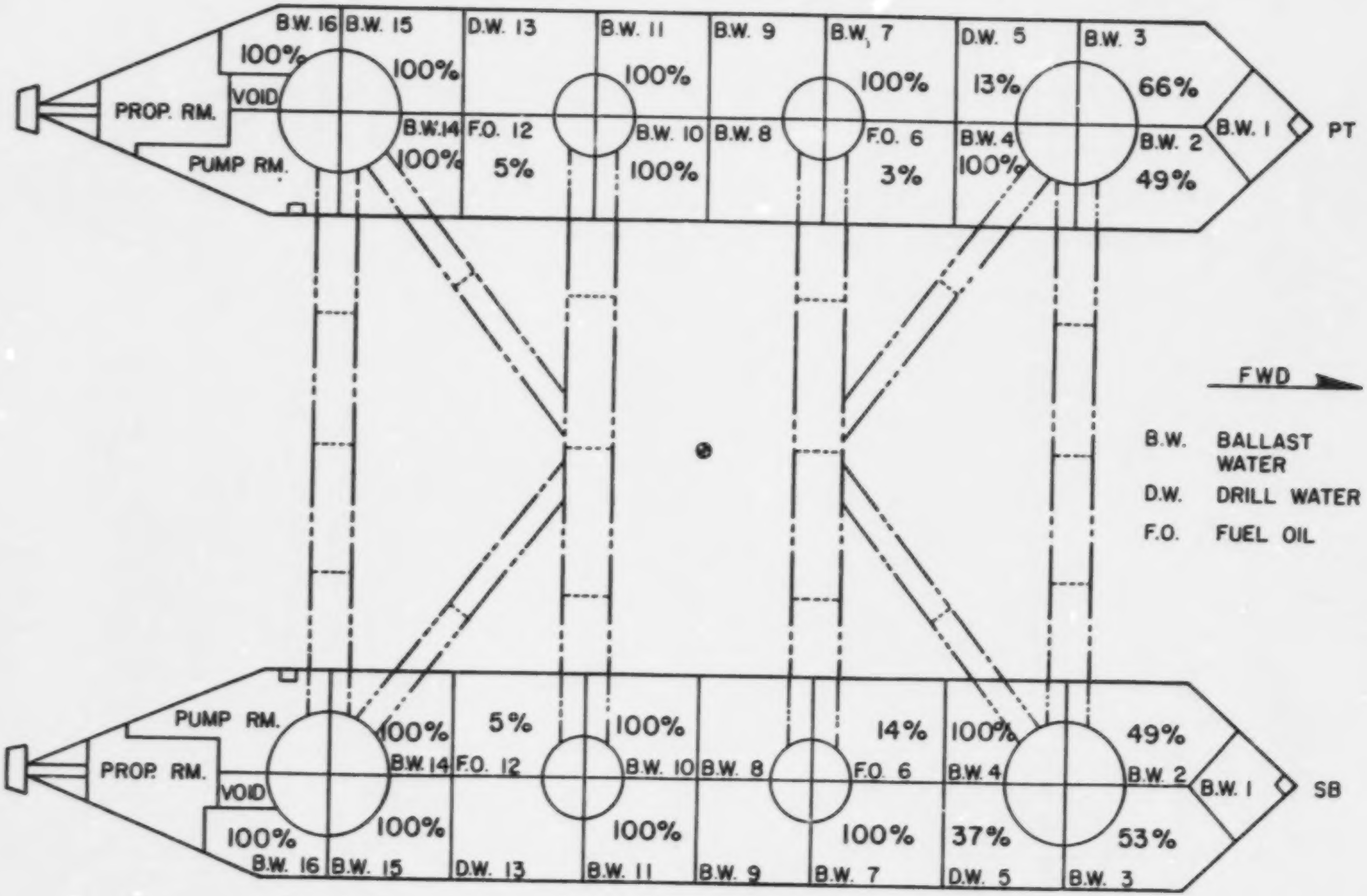

B.W. 16
B.W. 15
D.W. 13
B.W. 11
B.W. 9
B.W. 7
D.W. 5
B.W. 3
100%
100%
100%
100%
13%
66%
VOID
PROP. RM.
B.W. 1
PT
B.W. 14
F.O. 12
B.W. 10
B.W. 8
F.O. 6
B.W. 4
B.W. 2
PUMP RM.
100%
5%
100%
3%
100%
49%
FWD
B.W. BALLAST WATER
D.W. DRILL WATER
F.O. FUEL OIL
PUMP RM.
100%
5%
100%
14%
100%
49%
PROP. RM.
B.W. 14
F.O. 12
B.W. 10
B.W. 8
F.O. 6
B.W. 4
B.W. 2
B.W. 1
SB
VOID
100%
100%
100%
100%
37%
53%
B.W. 16
B.W. 15
D.W. 13
B.W. 11
B.W. 9
B.W. 7
D.W. 5
B.W. 3

Figure 2.3 Suggested Ballast Configuration

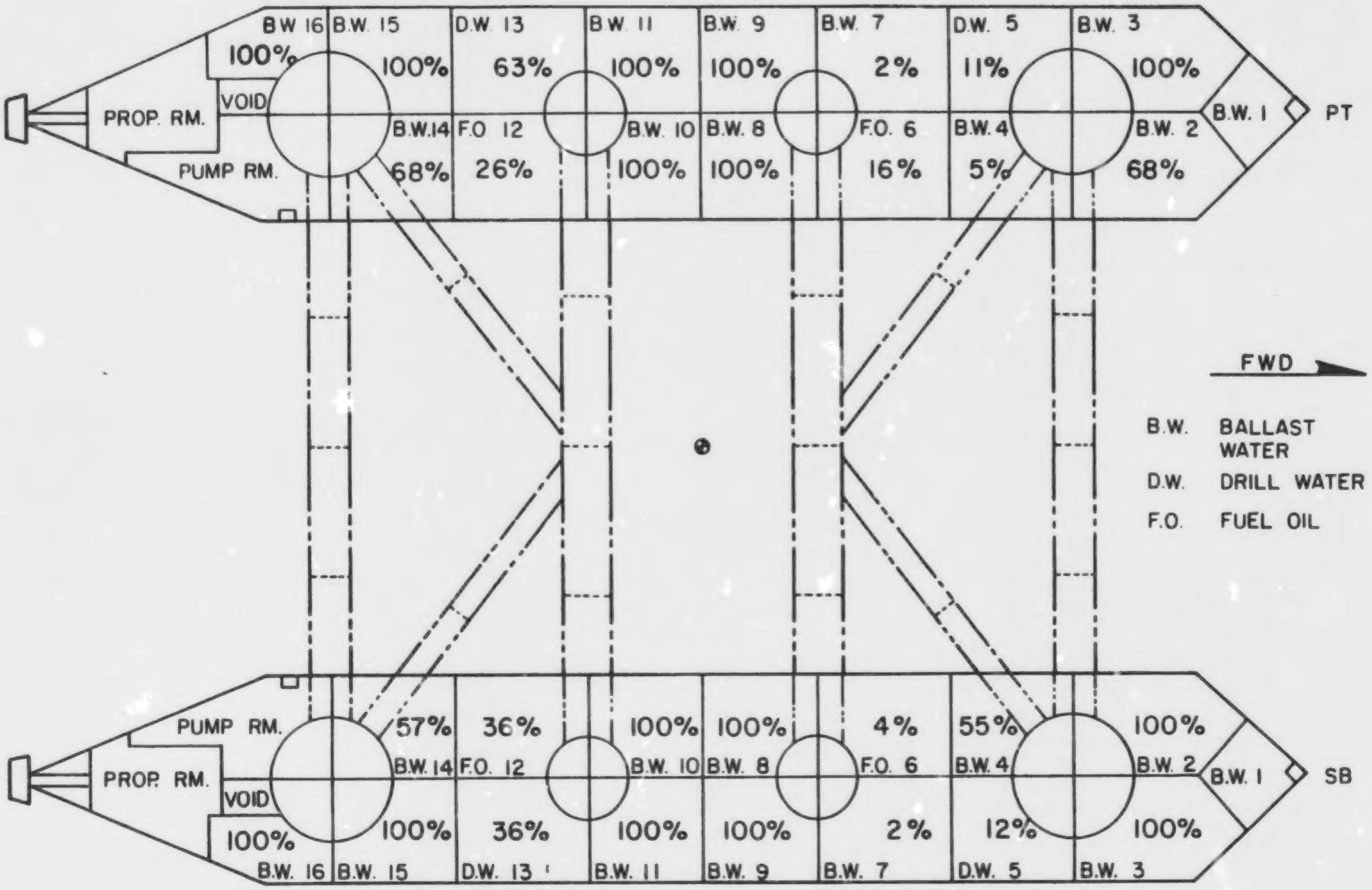

B.W 16
100%
B.W. 15
100%
D.W. 13
63%
B.W. 11
100%
B.W. 9
100%
B.W. 7
2%
D.W. 5
11%
B.W. 3
100%
VOID
PROP. RM.
PUMP RM.
B.W.14
68%
F.O 12
26%
B.W. 10
100%
B.W. 8
100%
F.O. 6
16%
B.W. 4
5%
B.W. 2
68%
B.W. 1
PT
FWD
B.W. BALLAST WATER
D.W. DRILL WATER
F.O. FUEL OIL
PUMP RM.
PROP. RM.
VOID
57%
B.W. 14
36%
F.O. 12
100%
B.W. 10
100%
B.W. 8
4%
F.O. 6
55%
B.W. 4
100%
B.W. 2
B.W. 1
SB
100%
B.W. 16
100%
B.W. 15
36%
D.W. 13
100%
B.W. 11
100%
B.W. 9
2%
B.W. 7
12%
D.W. 5
100%
B.W. 3

Figure 2.4 Lower Hull TAnk Configuration, February 14, 1982

CHAPTER 3 MOORING AND ANCHOR SYSTEM

3.1 General

The rig is rated for operational water depths of up to 3,000 ft. with twelve 45,000-pound Stato anchors. Each anchor has 5,600 ft. of 3.5 in. wire rope and 1,650 ft. of 3.25 in. chain for operation in water depths up to 1,500 ft. For operation at water depths up to 3,000 ft., each anchor may be equipped with 5,600 ft. of wire rope and 3,100 ft. of chain. The chain and wire rope have break strenghs of 1,210,000 pounds and a proof strength of 804,000 pounds. The normal 12 anchor mooring pattern is shown in Figure 3.1, and the inboard disposition of the mooring system in Figure 3.2.

When the anchor line is hauled on board the wire-rope drum is under power and supplying energy to pull the anchor line on board. This line passes over the wildcat, which is grooved to accept both the 3.5 in. wire and the 3.25 in. chain, and the lower sheave, similarly grooved. When the chain makes contact with the wildcat, it will be powered along with the wire-rope drum, and chain will start to move towards the lower sheave at the top of the chain locker. This lower sheave is not powered. The same DC motor powers both the wire-rope drum and the wildcat through separate clutches. When the chain moves just beyond the lower sheave, power is no longer supplied to the wire-rope drum and only the wildcat is hauling the chain, which falls into the chain locker.

Table 3.1 outlines the mooring deck equipment.

3.1.1 Anchor Setting

The minimum amount of line to be outboard of the lower fairlead (i.e., catenary) for a given line tension is a function of the water depth, and for the 260 ft. water depth at Hibernia, would be approximately 3,400 ft.. Ideally, the anchors should be set (i.e., the chains "tensioned up") in order to withstand the maximum anticipated environmental forces. Total forces on the rig due to wind, waves and currents are considered to be directed on the rig from the bow/stern, beam and diagonal directions. A restoring force due to the mooring equal to the above forces would place a maximum load (HLT anchor load) on one or two anchors. Normally it is assumed that the three leeward lines would be completely slack, and under this condition the maximum anchor load would be less. The anchor should be tested to this latter value for the maximum environmental condition.

Once again this is the ideal "setting" tension and may not be obtainable in the field. Some soils are weaker when anchors are first set, but after a period of "soaking" the anchor holding power increases substantially. The ultimate holding power for the 45,000 pound Stato anchor in mud after "soaking" is nominally about 430,000 pounds.

It should be pointed out that the diagonal force generally represents a "worst" case and normally the rig would be positioned to take the anticipated environmental forces on the bow.

3.1.2 Required Pre-Tensions

For normal operations, the anchor lines are slacked back to the required pre-tensions which for the Hibernia site would have been approximately 230,000 pounds. Under this pre-tension the anchor chain will reach one-third of the breaking strength (maximum chain tension during drilling mode) at barge offset equal to 6 percent of water depth. The actual mooring configuration with line lengths and pretension values are shown in Figure 3.3.

Initial survey of the rig using a remote controlled vehicle (RCV) indicated that anchor cables 1, 2, 4 and 5 were broken and the rig is resting upside down on the seabed with the derrick broken away. The location of the rig and the disposition of the anchor cables based on interpretation of side scan sonar data is given in Figure 3.4.

3.1.3 Survival Condition

Under survival conditions, at least two leeward lines should be completely slackened. Once the minimum tension is achieved, continued slackening of line will only place more line on bottom. There is no specific evidence that any line adjustment was carried out during the time leading up to the accident and it is assumed in the analysis that the lines were not slackened. A reserve of at least 200 ft. of wire should be maintained on the wire reel to ensure against accidental loss of the line.

3.2 Calculation of Anchor Line Tensions

An attempt has been made to determine whether the environmental conditions prior to the accident and the reported list of the rig could have caused excessive anchor line tensions.

3.2.1 Environmental Conditions

Based on available data the worst environmental conditions, in mooring terms, to occur around the time of the accident is given in Table 3.2.

3.2.2 Forces and Rig Displacements

Wind forces were calculated based on wind velocity, shape and projected area of the structural element and the elevation of that structural element. The wind forces calculated for beam and diagonal directions plotted against wind speed are given in Figure 3.5.

Current forces on semi-submersible hulls and column are largely generated by drag resistance. Frictional resistance is not significant and has been neglected in the analysis. Plots of current force against velocity are also given in Figure 3.5.

Wave drift forces were calculated for the waves assumed in 3.2.1 and are given in Table 3.3.

First order wave effects (surge and sway) are particularly significant in shallow water moorings. This is due to the stiffness characteristics or slope of the load-displacement curve of the catenary in shallower water depths, where comparatively small horizontal displacements generate large increases in tension. Wave energy and rig response spectra were produced for each relevant case: wind driven, swell and combined wave. The calculated motion amplitudes (± values from displaced mean position) are given in Table 3.4.

3.2.3 Calculation of Tensions due to Environmental Forces

Four cases were considered. Calculations were done assuming the rig to be at 58 ft. and 80 ft. drafts. The environmental conditions and forces for the four cases are given below.

CASE 1

Wind (Speed/Direction)	56 Knots/240°
Wave (H_S/T_S/Direction)	33 ft./12 secs./240°
Current (Speed/Direction)	0.5 Knot/240°

This produces a steady force of 530k and 480k for 58 ft. and 80 ft. drafts respectively and maximum wave displacement of 8.1 ft.. The rig is assumed to be level.

CASE 2

Wind (Speed/Direction)	45 Knots/270°
Wave: wind driven (H_S/T_S/Direction)	33 ft./11 secs./270°
Wave: swell (H_S/T_S/Direction)	23 ft./9 secs. /230°
Current (Speed/Direction)	0.5 Knot/240°

This produces resultant forces of 436k and 430k for 58 ft. and 80 ft. drafts respectively and maximum wave displacement of 8.3 ft. at 26°. The rig is assumed to be level.

CASE 3

Wind (Speed/Direction)	45 Knots/270°
Wave-wind driven (H_S/T_S/Direction)	33 ft./11 secs./270°
Wave-swell (H_S/T_S/Direction)	23 ft./9 secs. /230°
Current (Speed/Direction)	0.5 Knot/270°

This produces a resultant force of 700k for an 80 ft. draft and a maximum wave displacement of 8.1 ft. at 240°. The rig is assumed to have a 15° heel to port.

CASE 4

Environmental conditions similar to Case 3 are assumed. The rig is assumed to have a 15° heel to port with the most highly loaded line of Case 3 broken.

The summary of the analyses is given in Table 3.5.

3.2.4 Conclusions

The results given in 3.2.3 concentrate mainly on maximum line tension, as this is the most fundamental and useful indicator of a system's integrity and reserve of strength.

The Standard for mooring line strength generally followed in the industry gives a minimum safety factor of 2.0 against line breakage in extreme or survival conditions. That is, maximum line tension should not exceed 50 percent of the rated breaking strength of the line. This factor of safety relates to conventional quasi-static methods of analysis.

Case 3 gave the maximum line tension in the intact 12 line configuration - 535 kips or 44 percent of the basic line breaking strength.

Therefore the mooring lines on OCEAN RANGER would not have failed operationally due to overload, in the reported conditions.

Case 4 was a hypothetical case carried out to estimate the probable consequence of removing the most highly loaded of the wires reported broken at survey i.e. line numbers 1, 2, 4 and 5.

The removal of line number 1 increased the tension in line number 2 to 650 kips or 54 percent of its breaking strength, but decreased the tensions in line numbers 4 and 5 due to re-distribution of load in yaw.

Therefore line numbers 1, 2, 4 and 5 would not have failed progressively due to overload.

The criteria by which these conclusions have been reached relate only to failure by overload. None of the other potential causes of failure, such as axial or bending fatigue or corrosion wastage, are considered.

The reserve stength of individual mooring lines was calculated assuming that the actual ropes, chain cables and associated components were in satisfactory condition, with breaking strengths equal to or close to their original rated values.

3.3 Anchor Bolsters

3.3.1 Analysis of Damage

The underwater survey has indicated that the forward anchor bolsters are damaged. An analysis of the anchor bolsters was performed to study the forces developed in bolster members due to loads at the forward end of the bolster.

The port forward bolster was modelled using pipe elements (Figure 3.6). The circled numbers refer to member numbers and the others to node numbers. Unit loads were applied at nodes 40, 43, 46, 48, 49, 50 and 52 in three orthogonal directions and tensions calculated in all members. The critical direction of load application at any of the above nodes to produce maximum tensions in some of the members at the forward end was studied. The tensions in some of the members were an order of magnitude higher than the load. To check the analysis the bolsters were modelled by beam elements with equivalent stiffnesses; the results were similar.

3.3.2 Conclusions

Due to the configuration of the supports the main members could develop large tensions when they are loaded. Tension breaks could occur in the main members if the forward end scrapes the bottom.

Table 3.1

General Mooring Deck Equipment Capabilities

1) Brakes

- Winch brake (band and disc) minimum 1,248, 000 lbs
- Windlass brake (band and disc) minimum 1,210,000 lbs.
- Disc caliper brake run chain or wire rope at 200 ft/min. at 150,000 lbs. for extended periods of time (over one hour)
- Band brakes on winch and windlass can stop 150,000 lbs. at 500 ft/min. in 10 seconds

2) Power Drive (1,000 hp Westinghouse 370 DZ Traction Motor)

- Sprag brake, i.e., motor brake will not release until full load is taken by motor
- Dynamic payout of motor, i.e., motor acts like a generator, permitting slow controlled payout under high tension
- Haul-in characteristics of winch and windlass:

Stall-winch (624,000 lbs.) and windlass (605,000 lbs.)

Low speed 10 fpm - 470,000 lbs.
High speed 120 fpm - 110,000 lbs.

3) Lock Pawl

- Release windlass lock pawl at 1,210,000 lbs.
- Release winch lock pawl at 1,248,000 lbs.
- Both can be released without rig electric or air power.

4) Controls

- Complete control from local stand
- Complete control from ballast control room
- Emergency release from ballast control room

5) Other Features

- Chain and wire rope all stored on rig
- All line is run and retrieved in one operation without disconnecting the chain from the wire rope
- Continuous static and dynamic tension readout (recorded) and speed indicators

Table 3.2

Environmental Conditions, February 14, 1982

Case	Wind			Waves					Current	
	Speed Knots			Wind Driven		Swell				
	Recorded V_R	Effective V_{10}	Direction (° True)	Significant Height (Ft.)	Period (Secs.)	Significant Height (Ft.)	Period (Secs.)	Direction (° True)	Speed (Knots)	Direction (° True)
1	72	56	240°	33	12	-	-	-	0.5	240°
2	50	45	270°	33	11	23	9	230°	0.5	270°

V_R - Recorded wind speeds from wind sensor on OCEAN RANGER positions 79m above mean sea level.

V_{10} - Equivalent effective wind speed at 10m above mean sea level.

Table 3.3

Calculated Wave Drift Forces

Environmental Case	Significant Height (feet)	Wave Period (Secs.)	Mean Drift Force (Kips)
1	33	12	98
2	33	11	116
2	23	9	84

Table 3.4

Calculated Motion Amplitudes

Environmental Case	Significant Wave		Surge (ft)		SWAY (ft)		QUARTERING (ft)	
	Height (Ft.)	Period (Secs.)	SIG	MAX	SIG	MAX	SIG	MAX
1	33	12	5.0	8.6	4.4	7.5	5.1	8.7
	33	11	4.5	7.5	3.9	6.7	4.5	7.6
2	23	9	2.0	3.4	2.1	3.6	1.9	3.3
	40	-	4.9	8.3	4.5	7.6	4.9	8.3

Table 3.5
Summary of Maximum Line Tensions

	Highest Loaded Mooring Line			Next Highest Loaded Mooring Line		
Case	Line No.	Maximum Tension (Kips)	Percent Breaking Strength	Line No.	Maximum Tension (Kips)	Percent Breaking Strength
1	1	460	38	12	420	35
2	3	435	36	1	406	34
3	1	535	44	12	473	39
4	2	650	55	12	540	45

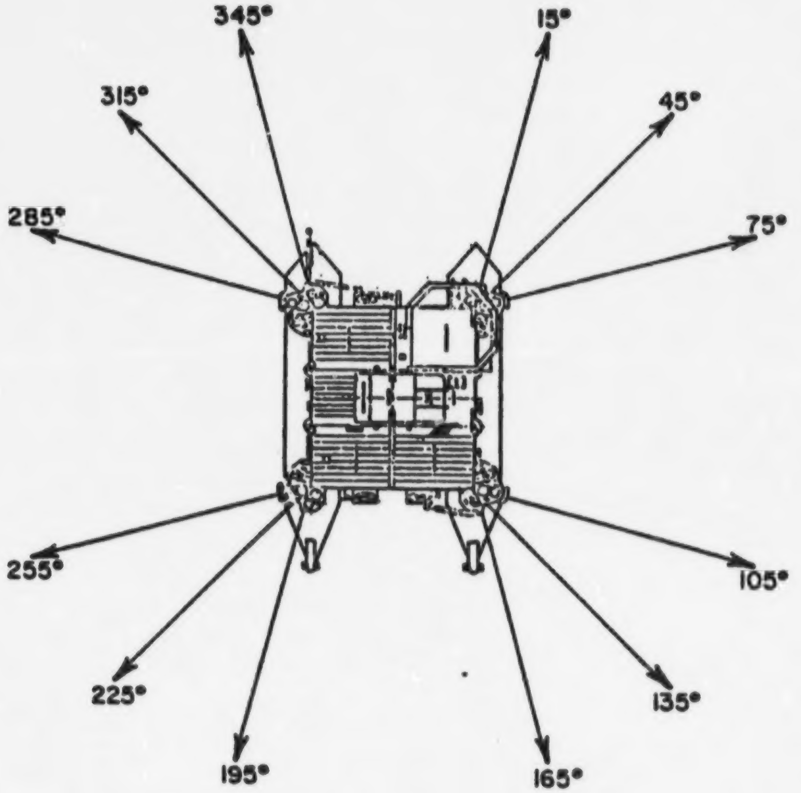

345°
15°
315°
45°
285°
75°
255°
105°
225°
135°
195°
165°

Figure 3.1 Mooring Pattern (15° - 45°- 75°)

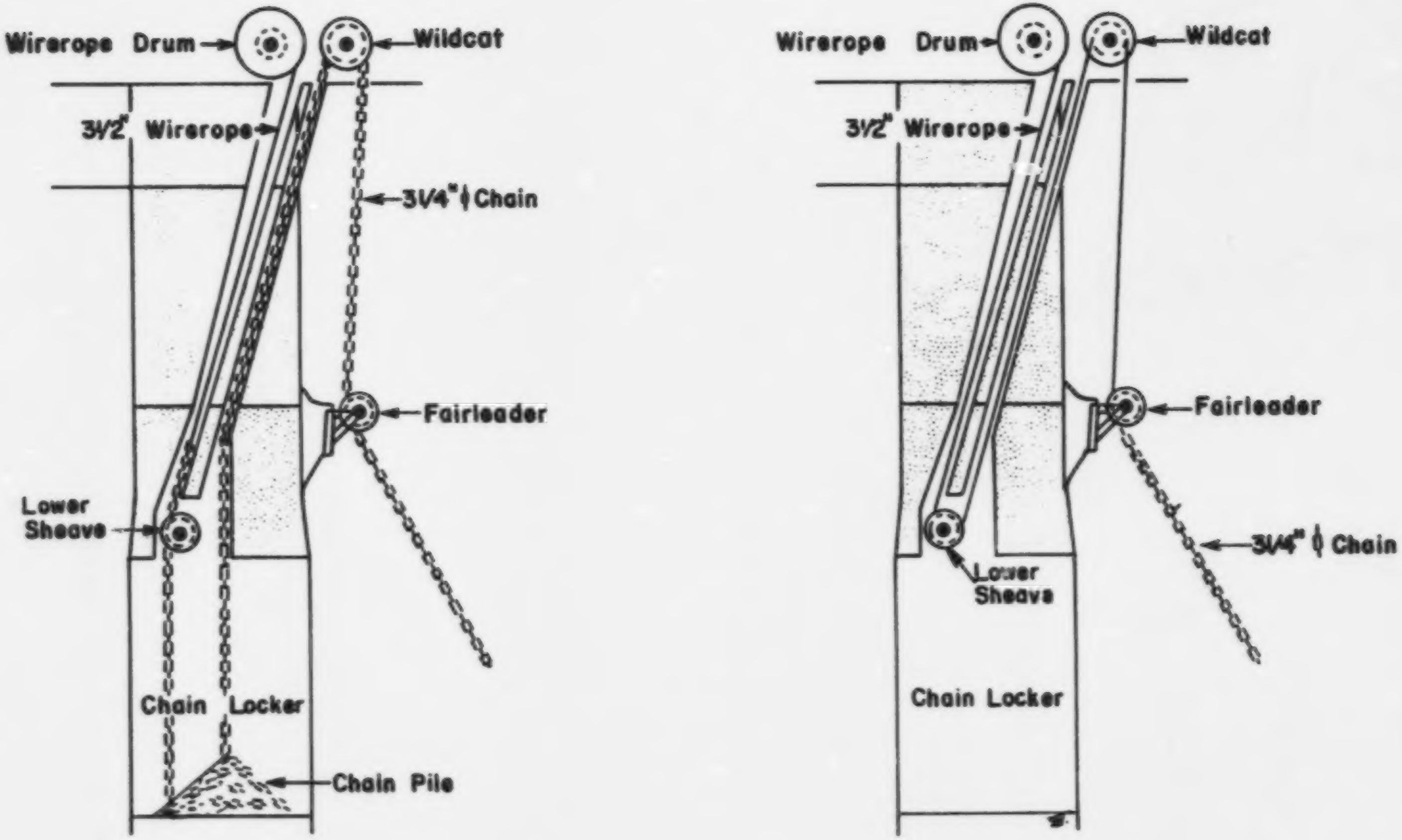

Wirerope Drum
Wildcat
3 1/2" Wirerope
3 1/4" ɸ Chain
Fairleader
Lower Sheave
Chain Locker
Chain Pile
Wirerope Drum
Wildcat
3 1/2" Wirerope
Fairleader
3 1/4" ɸ Chain
Lower Sheave
Chain Locker

Figure 3.2 Combination Mooring System

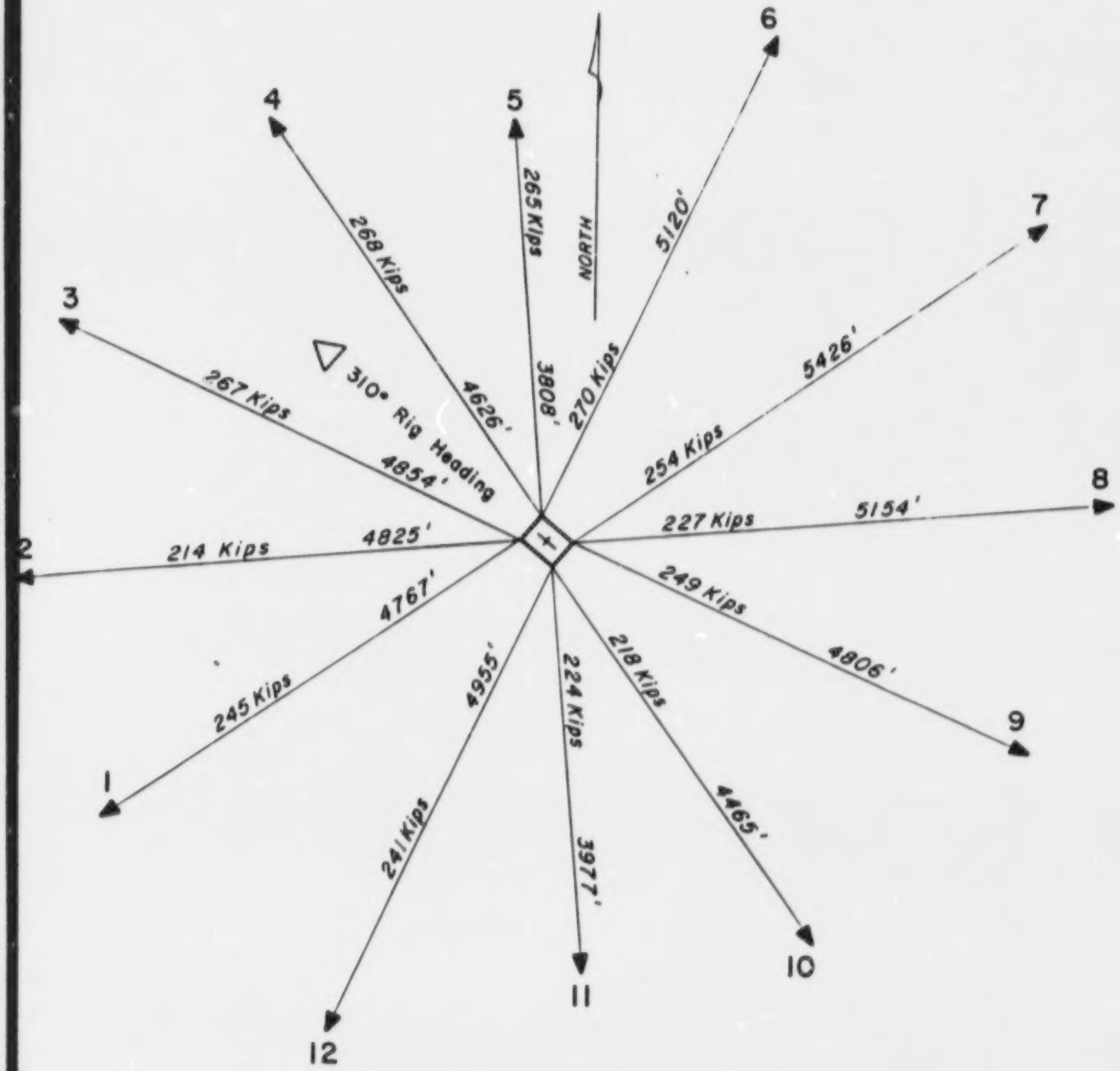
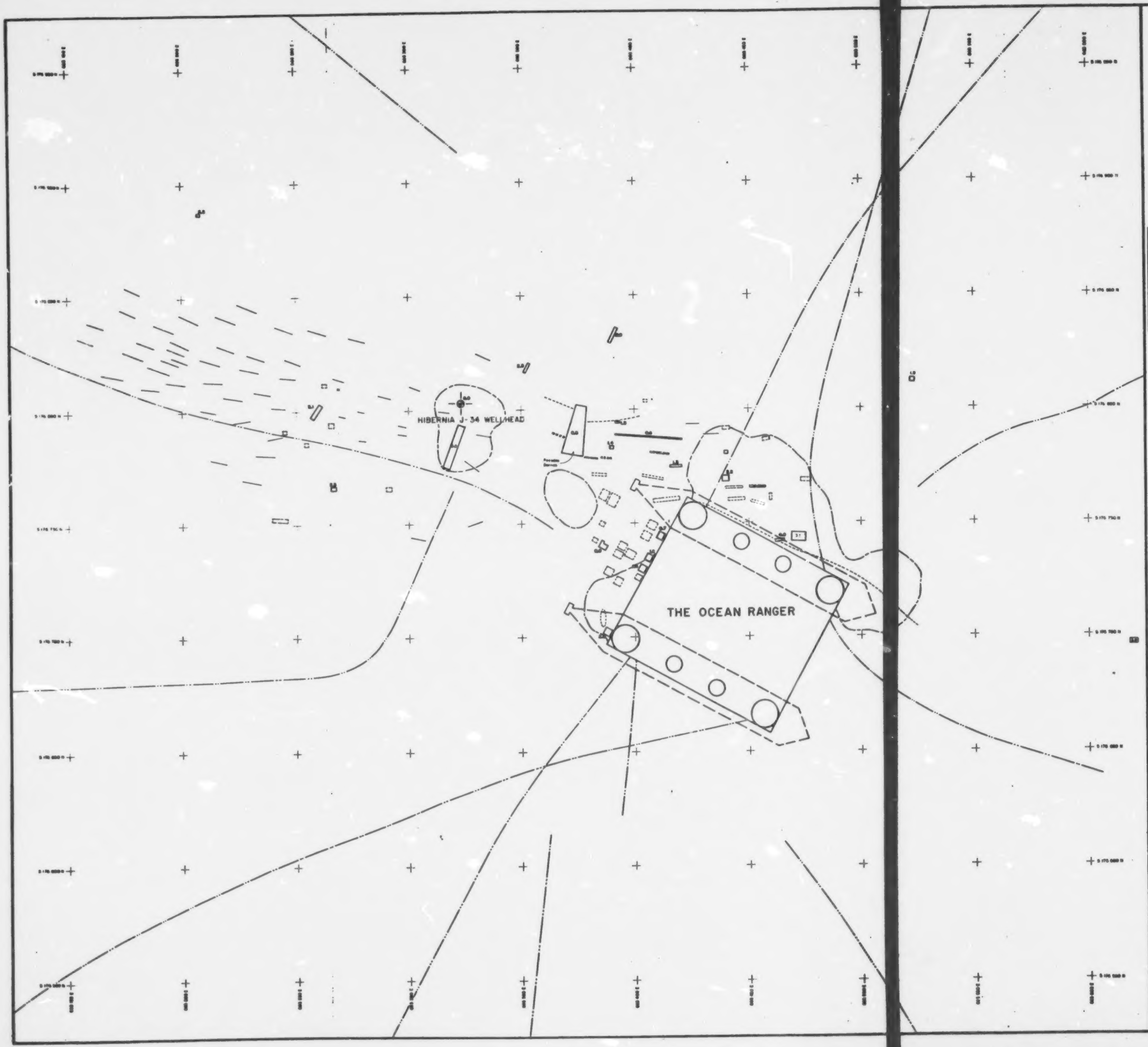
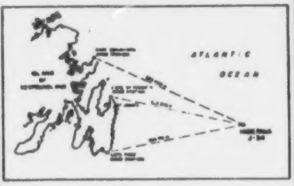

NORTH
1
2
3
4
5
6
7
8
9
10
11
12
310° Rig Heading
245 Kips
4767'
214 Kips
4825'
267 Kips
4854'
268 Kips
4626'
265 Kips
3808'
270 Kips
5120'
254 Kips
5426'
227 Kips
5154'
249 Kips
4806'
218 Kips
4465'
224 Kips
3977'
241 Kips
4955'

Figure 3.3 Hibernia J-34 Anchor Pattern



LOCATION DIAGRAM



LEGEND

17	DEBRIS WITH HEIGHT IN METRES POSITIONED TO HIGHER CONFIDENCE LEVEL PLOTTED TO SCALE
⬚	DEBRIS POSITIONED TO LOWER CONFIDENCE LEVEL PLOTTED TO SCALE
———	PIPE
- - - - -	SMALLER CABLES
—— - ——	ANCHOR CABLES
◌	AREAS EXHIBITING LOCALIZED SURFICIAL DISTURBANCES (SHALLOW GOUGING OR SCRAPPING)

NOTES

(A) THE PLOTTING ERROR DUE TO NAVIGATION, SHIP'S MOVEMENT, FISH POSITIONING, HEAVE, OFFSET AND SLANT RANGE IS CUMULATIVE. THE ERROR EXPECTED IN THE NAVIGATION SYSTEM ALONE, WITHIN THE 95% CONFIDENCE REGION, IS ± 25 METRES AND THE ACCUMULATION OF THOSE OTHER INFLUENCES DISCUSSED WOULD DETERIORATE THE ABSOLUTE ERROR EVEN MORE. ALSO, POSITIONING DONE DURING POOR PROPOGATION TIME FRAMES CANNOT BE CONSIDERED TO BE WITHIN THE 95% CONFIDENCE REGION.

(B) APPROXIMATE WATER DEPTH 70 METRES AT RIG LOCATION.

(C) RIG ORIENTATION AS PER MOBIL OIL CANADA'S VIDEO RECORDS.

(D) GENERAL CONFIGURATION AS PER OCEAN RANGER DATA SHEET.

(E) MEAN DRILL RIG LOCATION CALCULATED FROM SIDE SCAN RECORDS AND BASED UPON PRIMARY ARGO 54 POSITIONING DATA.

(F) INTERPRETED DIMENSIONS OF DEBRIS ARE DERIVED FROM SONAR RECORDS AND ARE ONLY APPROXIMATE.

Figure 3.4
Side Scan Sonar Data

SCALE OF METRES

MOBIL OIL CANADA
LIMITED

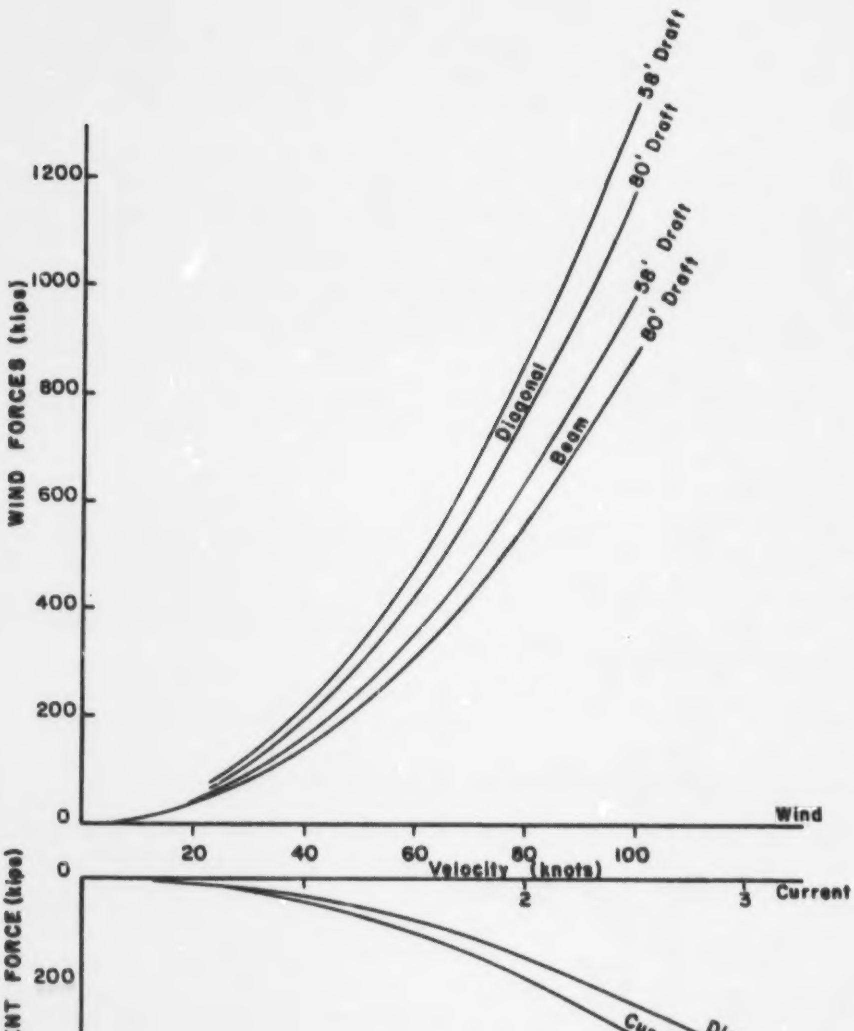
SIDE SCAN SONAR SURVEY
OCEAN RANGER SITE

PLAN A

INTERPRETED LOCATION OF OCEAN RANGER
DEBRIS AND ANCHOR CABLES

DATE [illegible]	CENTRAL MERIDIAN 51° W
SCALE 1:[illegible]	UTM CO-ORDINATES, ZONE 22
JOB NO [illegible]	DWG NO 1 of 1 · DWN [illegible]

McElhanney



. Figure 3.5 Wind and Current Forces

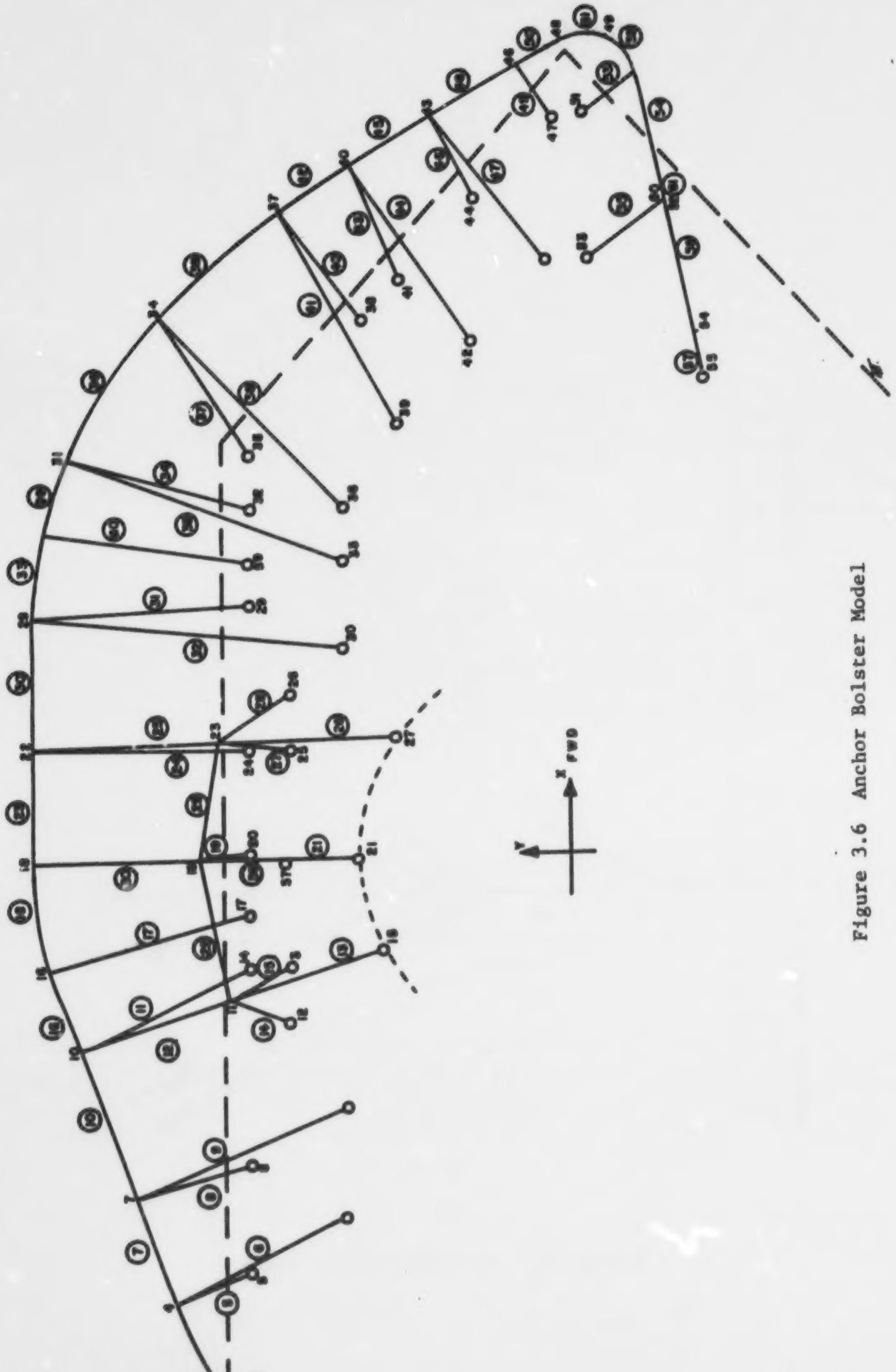


Figure 3.6 Anchor Bolster Model

CHAPTER 4 BALLAST CONTROL

4.1 Introduction

Ballasting the OCEAN RANGER to alter its draft, trim or heel is by means of seawater ballast tanks located in its pontoons, 12 to each side. In addition, each pontoon contains two fuel (inboard) and two drill water (outboard) tanks for a total of 16 tanks per side. The layout of the starboard pontoon is shown in Figure 4.1. The port pontoon is a mirror image of the starboard, reflected about the fore-aft axis.

All tanks are filled or emptied from pumps located in a room at the extreme aft inboard end of each pontoon, containing both the pumps and the air operated butterfly valves. Each system (ballast, drillwater, bilge and fuel) is independent, although cross connections exist among the first three. Ballast material is seawater, obtainable from a large (18 in. diameter) sea chest valve inlet through the inboard side of the pump rooms, at the base level of the pontoon. Excess sea water is pumped overboard via a discharge pipe.

Valves and pumps are normally controlled centrally from a remote panel in the control room located at the 32m level of the SC-3 column (Figures 4.1A, 4.1B and 4.1C).

4.2 Mechanical Aspects of the Ballast Control System

4.2.1 Ballast Piping System

The ballast piping system in each pontoon is identical, the only cross-connection between the two systems being via a single ballast pump discharge line across the cellar deck.

All ballast piping material is of carbon steel.

The ballast piping system in each pontoon consists of three interconnected pipelines, which come together in a tee:

(a) Ballast Main

(b) Ballast Suction Main

(c) Ballast Discharge Main

4.2.1.1 Ballast Main

This 18 in. diameter line is the connecting pipeline for all the individual 8 in. diameter ballast tank branch lines, each branch being connected to the Ballast Main via a remote operated butterfly valve (R.O.V.).

4.2.1.2 Ballast Suction Main

This 18 in. diameter line has directly connected to it the ballast main, the three ballast pump suctions, the sea suction chest and three emergency bilge suctions, all connected via remote operated butterfly valves. In line with the sea suction chest is a manual, normally open valve as well.

4.2.1.3 Ballast Discharge Main

This 16 in. diameter line has directly connected to it the ballast main, the three ballast pump discharge lines and the overboard discharge line, all connected via remote operated butterfly valves and non-return valves. The non-return valves, located on the discharge side of the pumps, allow any combination of pumps to be used simultaneously in parallel to increase capacity.

4.2.1.4 Piping Systems Interconnection

(Refer to Figures 4.2 and 4.3)

4.2.1.4.1 Bilge

There are two bilge pumps per side, located in the pump room. Normally, one pump is connected to the pump room bilge and the other to the propulsion room bilge. If necessary, either can be connected to the void in the pontoon by a manually operated valve. Each pump can back up the other via a manual crossover valve, and each is equipped with its own (manual) suction and discharge valves. All valves are equipped with indicators that are displayed on the control room mimic panel.

The ballast system is not connected to the bilge system. The ballast suction main is however fitted with three emergency bilge suctions directed to the following spaces:

(i) Pump Room

(ii) Propulsion Room

(iii) Pump Room Void Space

4.2.1.4.2 Drill Water

The drill water system in each pontoon is connected to the ballast system via the following cross-connections:

(i) Between the drill water suction and the outboard ballast pump suction chest in the pump room.

(ii) Between the drill water discharge main and the outboard ballast pump discharge in the pump room.

The effect of this configuration is to allow the possibility of internally pumping ballast from one tank to another. Water may be pumped from any ballast tank into the drill water service filling line and either drill water tank, if they are empty. It may then be pumped from the intermediate drill water tank back into the ballast water system to any desired tank.

This is not a normal operation but a possible course of action.

4.2.1.4.3 Fuel Oil

There are no direct cross-connections indicated between the two fuel oil tanks and either the ballast or the drill water systems. However, manual hose connections could be made between the salt water day tank or the fire fighting system into the fuel service line. As well, the drill water service line could be fed into the fuel line. Fuel oil could be fed from the fuel oil day tank into either the ballast system or the drill water service line.

4.2.1.5 Valves

(i) All ballast, drill water and fuel oil tank isolating valves for pontoon tanks are located in the pump room.

(ii) All the valves incorporated in the ballast system, with few exceptions, are remotely operated butterfly valves. (R.O.Vs) The operation of the valves is air open - spring close, providing automatic closure in the event of air loss. Air supply to each valve is by an individual line from the control room reservoir.

The following valves are not remotely actuated from the ballast control room:

(a) The manually operated sea chest isolating gate valve which duplicates the sea-water suction remote operated butterfly valve to the ballast suction main.

(b) The ballast system overboard discharge screw-down nonreturn valve which duplicates the overboard discharge remote operated butterfly valve.

(c) Non-return valves located on the discharge side of each ballast pump and drill water pump and on the emergency bilge suctions.

4.2.1.6 Ballast Tank Air Vent System

4.2.1.6.1 Air Pipes

All air pipes from the tanks in the pontoons are routed through the columns to the cellar deck. All air pipes terminate with air pipe vent heads.

4.2.1.6.2 Air Pipe Vent Heads

Air vent heads are fitted with oil impregnated wooden float plugs. The float plugs will seal off the vent heads to prevent flooding if the vent heads should become submerged.

The float plugs may be locked in any position between fully closed and fully open via a wing nut.

4.2.2 Ballast Pumps

4.2.2.1 Location

Three ballast pumps are located in each pontoon, the location being as follows:

(a) Port Pontoon

No. 1 Ballast Pump	Pump Room outboard side
No. 3 Ballast Pump	Pump Room inboard side
No. 5 Ballast Pump	Propulsion Room (powered by emergency supply system)

(b) Starboard Pontoon

No. 2 Ballast Pump	Pump Room outboard side
No. 4 Ballast Pump	Pump Room inboard side
No. 6 Ballast Pump	Propulsion Room (powered by emergency supply system)

It is noted that all the ballast pumps are located in the after end of each pontoon.

4.2.2.2 Type

The ballast pumps are of the vertical deepwell type (Figures 4.4 and 4.5).

4.2.2.3 Capacity

Capacity and performance curves for the upper impellor, lower propellor and the overall pump are as shown in Figures 4.6, 4.7

and 4.8. The manufacturer's guaranteed performance is for

2000 gallons/minute at 170 ft TDH
($546m^3$/hour at 52m TDH)

4.2.2.4 Operation

4.2.2.4.1 Ballasting

(i) Ballasting can be carried out separately for each pontoon by pumping up the ballast tanks, using any combination or all of the ballast pumps and tanks.

(ii) Ballasting can also be carried out by flooding. This is achieved through the normally open manual sea chest valve by opening the remote operated butterfly valves at the sea chest and those connecting the ballast suction main to the ballast main. Each tank can then be flooded directly from the sea by opening its individual valve.

It is considered that there may be less control over ballasting while flooding than there would be when pumping. The ballasting rate can be controlled by the number of pumps employed at any time. Control over the rate of flooding is via the remote operated butterfly valve at the ballast main. This valve can only be placed in the open or closed position.

4.2.2.4.2 Deballasting

Deballasting is carried out by pumping out the ballast tanks via the ballast pumps. For emergency use, the ballast can be pumped using the drill water pumps.

4.2.2.4.3 Tanks

To maintain control over ballasting, one tank only should be used at any time in each pontoon. With more than one

i) uneven ballasting or deballasting between the open tanks may occur.

ii) cross-flooding may occur between the ballast tanks.

4.2.2.5 Priming of Ballast Pumps

From the information available, there does not appear to be any independent method of priming the ballast pumps. Information on the self-priming capability of the ballast pumps from the "dry" condition has not been made available. From the information available, the methods of priming the ballast pumps that could be employed are:

(a) Priming the ballast discharge main and the pump from the S.W. tank located at the cellar deck. Plans indicate, however, that each ballast pump is fitted with a non-return valve on the pump discharge.

The non-return valve will prevent each ballast pump "motoring" under the pumping action of other pumps that are running, but it will prevent priming of the pumps by filling the pump casings from the S.W. tank. This method of priming therefore would have limited success.

(b) Priming the ballast pumps by taking a suction from a tank with a positive head relative to the pump. This method will be effective, if supervised correctly and will have little effect on the overall ballast condition in the pontoon provided once the pump has been primed, it is switched to the tank requiring deballasting. A full tank used for priming may contribute a "free surface effect" to the stability after priming has been performed.

(c) Priming the ballast pumps by opening the sea suction valve and closing it again after priming is completed. The disadvantage of this method of priming is that the ballast system is usually set up for pumping out ballast when the pump may require priming. In this condition, opening the sea-suction valve will create a positive head in the ballast suction main which will effectively prime the ballast main, causing the tank opened for pumping out to fill. From a preliminary study, it may be possible for a positive head to exist in the ballast main in this condition even with all three ballast pumps running, fully primed and discharging overboard. At best, this condition will prevent deballasting the tank (if it is full) and at worst flood the tank (if it is empty).

4.2.3 Ballast System Operation Failure

4.2.3.1 Sea Inlet Valve

If the sea inlet valve remained in the open position, the situation described in 4.2.2.5 (c) could arise, causing the ballast tank open to the ballast system to fill and not to empty as required.

For the sea inlet valve to be in the open position in error, some possible causes may be as follows:

(i) A control system fault causing the valve to open or remain open.

(ii) An operator error, such as opening the valve by mistake, or leaving the valve open in error, either electrically via the control panel or by the manual override controls.

(iii) Mechanical failure of the valve causing it to remain in the open position, irrespective of the control system command.

(iv) Debris trapped inside the valve causing incorrect seating of the valve when attempting to move to the closed position.

(v) Use of the sea valve to prime the ballast pumps, then allowing the valve to remain in the open position as described in 4.2.2.5.(c) above.

4.2.3.2 Ballast Tank Valves

(a) If any two or more ballast tank valves are left in the open position at any time, the ballast tanks would be in direct communication via the common ballast main. As a consequence, the ballast in the tanks may cross-flood. If the two tanks involved were a forward ballast tank and an aft ballast tank then ballast may possibly level out by running from aft to the forward position, depending upon vessel trim and the contents of the tanks. The resultant increase in trim by the head caused by the shift in ballast would further increase the flow forward until either the aft tank emptied, the forward tank filled, or the two tanks levelled out.

Possible causes for this situation to occur to the ballast tank valves may be any or a combination of reasons (i) to (iv) given in 4.2.3.1; or if the operator attempts to perform a ballasting operation on two or more tanks simultaneously.

(b) It is noted that leveling could also occur between drill water tank numbers 5 and 13 or between fuel oil tank numbers 6 and 12, in an exactly analogous manner.

(c) There are no connections shown between Ballast/Bilge/Fuel Oil systems that could adversely affect trim or list. Therefore, incorrect operation of or damage to the system will not cause accidental cross-flooding between these various systems.

(d) Incorrect operation of the cross-over valves between the ballast and drill water systems coupled with incorrect operation of the drill water tank valves could cause cross-flooding with the ballast system or flooding of the drill water tanks from the sea.

(e) A single valve failure could lead to accidental flooding of a tank during ballasting operations. In this mode, failure of a single tank valve will result in flooding when the ballast suction main is open to the sea.

4.2.3.3 Pumps

(a) As is evident from Figure 4.7, the net positive suction head required by the 10P propellor is asymptotic with flow. The values given on the curve are for flow ranges from 3000 U.S. gall./min. to 4200 U.S. gall./min. The curve levels off at 19 ft. for flows of 3000 U.S. gall./min. and less, giving the net positive suction head required for the range under consideration as 19 ft. The suction lift capacity is thus determined as 13.8 ft. assuming atmospheric pressure to be 14.7 lbs./in.^{2}, the vapour pressure of sea water at 40°F to be 0.12 lbs./in. and the specific weight of seawater to be 64 lbs./ft.^{3}.

$$L = \frac{P_s - P_v}{\delta} - (NPSH)_r$$

where

L = suction lift capacity

P_s = absolute pressure at liquid surface

P_v = vapour pressure of liquid

δ = specific weight of the liquid

$(NPSH)_r$ = net positive suction head required for cavitation free operation.

(b) The major and minor losses of the ballast suction piping are tabulated from the piping drawings in Table 4.1. The associated head losses for the system are calculated using the Colebrook and Darcy-Weisbach equations. The results shown in Table 4.2 are pure head loss but Table 4.2.A incorporates an additional velocity head term.

The calculations were performed under the following assumptions:

i) The pumps, when primed, are capable of maintaining a suction head.

ii) The pumps are well maintained and in good working order.

iii) The pumps are operated correctly.

iv) The ballast system pipework has approximately doubled in its roughness from original construction.

iv) The valves associated with the ballast system pipework are in a well maintained condition and do not leak when in the closed position.

(c) When the unit is on an even keel, the system characteristics for either one or two pumps taking suction from either one or two laterally adjacent ballast tanks can be summed up by the curves shown in Figures 4.9 through 4.13. Deterioration over the years can change the pump characteristics so that the pump capacity curve in Figures 4.9 through 4.13 is approximate. The system head curves are made up of an increase in static head, i.e., lifting the water from the tank surface level to the overboard discharge at the 105 ft. level (zero level is the bottom of the ballast tank), plus the resistance in suction line and a velocity term. When the tanks are full the tank surface level is 35 ft. (55 ft. for tank number 1) and near empty is taken as 3 ft. If the level falls below 3 ft. a vortex (whirlpool) is likely to form around the inlet bellmouth, thereby allowing air to enter the suction line. The static head rise is the same for each pump/tank configuration, while the suction line resistance depends on the particular pump/tank alignment.

The 'maximum system head' curve (dashed line at 116 ft.) indicates the maximum head the pump can supply without cavitating.

The normal operating point for a given pump/tank configuration is at the intersection of the particular system head curve and the pump capacity curve. For example, using the curves for tanks 8 and 9, one pump taking suction from two full tanks will supply a total head of 89 ft. and flow 2900 GPM. As the tank is emptied, the operating point moves up along the pump capacity curve. If cavitation could be neglected the operating point would finish at the intersection of the empty tank curve and the pump capacity curve at 119 ft. head and flow 2750 GPM. However, because the intersection of the curves is in cavitation region, the operating point will move up the pump capacity curve until it meets the maximum system head curve at 116 ft. and 2775 GPM. From there the operating point will move horizontally along the maximum system head curve until the empty tank curve is reached at 116 ft. and 2400 GPM.*

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* Pages 2 and 3 of "OCEAN RANGER Ballast Pump Analysis", David Taylor Naval Ship Research and Development Center.

When the unit is in a pure trim condition by the bow, the system head curves must be raised by an amount equal to the vertical drop of the suction line inlets. Referring to Figures 4.9 through 4.13 the starting points for the empty tank and full tank system head curves must be raised to the levels indicated by the list angle scales.

The angles of trim to give loss of suction for empty and full tanks are summarized below, from the system head curves.

Ballast Tank Number	Angle of Trim To Loss of Suction (Empty Tank)	Angle of Trim to Loss of Suction (Full Tank)
1	3.0°	13.9°
2 and 3	3.3°	11.3°
4	4.2°	13.7°
7	5.3°	17.4°
8 and 9	6.8°	22.2°

(d) It should be noted from the system curves that as the unit is trimmed by the bow, the capacity of the pumps is reduced, due to cavitation. For each tank there is a particular angle at which the pumps cease to function, even when the tank is full. It is quite possible for the unit to be in a condition of trim that may not be readily corrected by deballasting.

(e) A particular feature of the unit is its lack of ullage in the after tanks. The rig's weight distribution is such that it is necessary to keep more ballast in the after tanks. In a trim by the bow condition it is not possible to correct the situation by flooding the after tanks, if they are already full. The single main method of correction is by deballasting, which decreases in efficiency with the trim angle as in 4.2.3.3.(d).

4.3 Electrical Aspects of the Ballast Control System

4.3.1 Power Distribution

4.3.1.1 Main Generators and Buses

The rig is equipped with two main generators (ratings: 450V. 3 Phase, 60 Hz, 1750 KVA, 1400kW), each apparently capable of running the entire rig. Each feeds into the main bus for powering the entire rig.

4.3.1.2 Emergency Generators and Buses

A separate emergency generator (rating: 450V, 3 Phase, 60 Hz, 1208kW,) is available, with its own distribution bus. The emergency bus is normally powered via the main bus and in the event of a power failure it is isolated from the main bus and supplied via the emergency generator. The major systems run off this bus are listed in Table 4.3.

4.3.2 Analysis of Flooding or Other Casualty on Electrical System

4.3.2.1 Effects of Flooding or Other Casualties

The effects of flooding or other casualty on the electrical system has been considered using a single fault concept; the details are given below.

Failure Considered	Possible Cause	Ballast Pumps Available*
Loss of main power	Fire in machinery space. Flooding in machinery space. Switchgear busbar fault.	5 and 6.
Loss of either main generator No. 1 or No. 2	Prime mover failure. Generator failure. Electrical fault.	All ballast pumps.
Loss of Emergency power	Fire in machinery space. Flooding in machinergy space. Emergency switchboard fault.	1, 2, 3 and 4.
Loss of emergency generator	Prime mover failure. Generator failure. Generator incomer fault.	All ballast pumps.
Loss of MCC4 or MCC5	MCC busbar fault. Feeder cable fault.	1, 3, 5 and 6 or 2, 4, 5 and 6
Loss of stbd. or port pump room	Fire in pump room. Flooding in pump room.	1, 3 and 5 or 2, 4 and 6
Loss of ballast control console	Fire in ballast control room.	Not known; See 4.3.2.2. (d)
Damage to cable run	Fire in any one compartment	Not known; See 4.3.2.2. (e)

---

* It is assumed above that a watertight bulkhead separates the main ballast pumps from the ballast pump motor; and that the starter is fed from the emergency switchboard.

4.3.2.2 Effects of Flooding or Other Casualty Not Able to be Determined

It has not been possible to establish the following, due to lack of information:

(a) That the circuit breakers and fuses in the main and emergency switchboards and MCC's 4 and 5 are suitable for the prospective fault currents.

(b) That satisfactory discrimination exists between protective devices i.e., fuses and circuit breakers in the supply system to MCC's 4 and 5.

(c) That loading or preference tripping arrangements are such as to ensure continuation of power supply to the running pumps under system overload conditions.

(d) That a common mode failure in the ballast pump control circuits would not prevent all ballast pumps from working e.g., that a fire in the ballast control console would not cause both the remote and local starting circuits of all pumps to be open circuited.

(e) That power and control cables for the ballast pumps are separated such that a fire in any one compartment could not put all of the pumps in one or both pump rooms out of action.

(f) That the arrangements for starting the standby main generator and emergency generator are such as to ensure security of electrical supplies.

Subject to satisfactory arrangements being provided to meet Section 4.3.2.2, it is considered from the plans examined that on a single fault basis, the electrical system would not constitute a hazard to the unit.

4.4 Control Aspects of the Ballast Control System

In the course of the appraisal consideration has been given to the following: (a) ballast pump controls; (b) ballast valve controls and associated power sources; (c) ballast tank gauging arrangements.

4.4.1 Layout of the Control Panel

The mimic panel in control room is accurately laid out and is the clearest available reference for describing the piping and valve arrangements (Figure 4.2). The control panel consists of a vertical section, containing auxiliary gauges and alarms (e.g. ammeters for the ballast pumps, watertight door alarms) and a horizontal panel upon which is inscribed the mimic diagram.

This consists of two L-shaped sections, one each for the starboard and port pontoons. One peculiarity of this arrangement is that the two sections are joined at the centre so the operator sees the two hulls with their bows pointing at each other, at right angles to their physical orientation, a possible source of confusion under crisis conditions.

The mimic diagrams includes all fluid control systems (ballast, fuel, drill water and bilge) with colour coded lines to distinguish them. Piping diameters are marked, with large diameter pipes highlighted by heavier lines. Controls (on and off switches for the pumps, and open and close switches for the remote operated valves) and indicators (built into the preceding controls as well as open/close indicators for manually operated valves) are located on the diagram at their respective positions. Thus control valves for the individual tanks are shown in their respective tanks, although all valves are physically located in the pump rooms.

4.4.2 Ballast Pump Controls

4.4.2.1 Operational Arrangements

The ballast pumps are arranged to be started and stopped by means of push button switches situated on the port and starboard ballast control mimic diagram panels.

It is concluded that the above push buttons are connected directly to their respective motor control centres.

4.4.2.2 Indication of Operational Status

Three means have been provided by which the operator is informed of the ballast pump operation:

(a) Running and stop lamps (green and red respectively) on the mimic diagram panels indicate whether a pump motor contactor has operated.

(b) Pump discharge pressure indicators which show that pumps are rotating and primed.

(c) Ammeters, indicating pump motor load, allowing the operator to deduce when liquid is being pumped.

4.4.2.3 Common Mode Failure

(a) Plan No. NMA 298-3A shows a single power source for the pump running/stop lamps and for the pump discharge pressure indicators. These could therefore fail simultaneously as a result of a single fault.

(b) Providing power was still available at the motor control centres, the pumps would continue to run and the ammeters would still provide indication.

4.4.2.4 Controls, Alarms, and Safeguards

(a) The ballast pumps have simple on/off controls as stated in 4.4.2.1 above.

(b) There would appear to be no alarms associated with the pump control circuits, nor indication of motor overload/trip at the ballast control console.

(c) There are no system safeguards incorporated in the ballast control circuits at the ballast control console.

4.4.3 Ballast Valve Controls and Associated Power Sources

4.4.3.1 Ballast Valve Air Supply

There are 3 rig compressors and a bulk air compressor (for general low pressure air), all connected to a main rig air supply, with at least two 100 cubic foot receivers at the source end. One branch of the main supply is tapped into the control room, which is provided with its own 27 cubic foot receiver. The supply is then split, one side going to the tank level indicator system and the other to the control panel.

In the panel, the supply is fed to five parallel manifolds each feeding ten or eleven solenoids. Each solenoid valve is attached to a copper tube that runs down to the individual R.O.V.'s, via, in the caissons, "multitubes" -- bundles of copper piping carrying 7 tubes per bundle. Drain traps and lubricators are located at the bottom, followed by a speed valve before connecting to the R.O.V.

4.4.3.2 Operational Arrangements

(a) The ballast valves are operated by push button switches on the ballast control mimic diagram panels. When one of the "open" buttons is pressed, its normally-open contacts close and energise a relay which self-holds via the normally closed contacts of the "close" button for that valve. A solenoid valve in the ballast control console is energised when the relay operates, and air is introduced to the ballast valve actuator to operate the valve to the open position (Figure 4.14). When the "close" button is pressed the relay de-energises and the solenoid control valve moves to the vent position releasing air from the valve actuator, which is of the spring close type, thus closing the ballast valve (Figure 4.15).

(b) The latching characteristic of the relay circuit introduces a possible hazard. If the "open" push button contacts or the sustaining contacts of the relay are momentarily made by shock or vibration or are temporarily bridged by conducting particles or liquid the relay will hold in and cause the associated ballast valve to open.

(c) The switches for controlling the valves are vulnerable to water, in light of the fact that they are not waterproof and given the close proximity of the control panel to water. This is a result of the presence of port holes despite the unusual location of the control room.

4.4.3.3 Indication of Operational Status

(a) The port and starboard ballast systems each have two manually operated valves, one for the sea inlet, and the other for the overboard discharge. Lamps are provided on the ballast control mimic panels to indicate when these valves are fully open or fully closed, via limit switches located at each valve. While between extreme positions neither the open or closed lamps are lit.

(b) The remotely controlled ballast valves are provided with similar indication lamps fitted within the "open" and "close" control push buttons. The circuits of these lamps include contacts of the selection relays in series with the micro switches on the ballast valves. The purpose of this arrangement is not apparent since it introduces a degree of separation between the indication and the function to be indicated. If a valve were to be opened by means of its local manual control the "close" lamp would be extinguished, but the "open" lamp would not be lit.

As well, some uncertainty is introduced when both the open and closed lamps remain unlit after the normal travel time of the valve. The operator is able to check his lamps but cannot distinguish between a faulty valve or a faulty limit switch.

(c) The air piping diagram for the solenoid valves shows that a pressure gauge is provided to indicate the air supply pressure for the ballast valve system.

4.4.3.4 Common Mode Failure

(a) Neither the electrical nor air supplies are shown to be duplicated. Failure of either service would cause all remotely operated valves to close. This would halt any ballasting operation in progress only until power could be restored or the necessary valves opened manually. While this failure mode could be described as "fail safe", the system could be improved by the provision of standby power supplies.

(b) Cutting off the electrical or air supply to the ballast control console could provide a useful means of effecting total shut down of the system in the event of control system malfunction.

(c) Short circuit of the indicator contacts by water particles may energize both the "open" and closed lamps (Figures 4.14 and 4.15). As well, the short circuiting may produce fluctuations in the lamps, possibly leading the operator to believe the valves are opening and closing. It must be remembered that it is also possible to short the control circuit and actually open the valve. The two possibilities make it difficult for the operator to determine exactly what is happening in such a situation.

4.4.3.5 Controls, Alarms, and Safeguards

(a) Ballast valve control is effected by the push button circuits described in 4.4.3.2 (a) above. There are no means of partially opening any of the remotely operated valves, or of indicating any position other than fully open or closed.

(b) There would appear to be no alarms provided for the ballast valve control system. Present ship rules require audible and visual alarms for the failure of power supplies to control systems. In this case both the electrical and air supplies would require failure alarms. Any of the lamps which fail to operate as expected may be checked for continuity via the lamp test circuit from the control panel.

(c) Fuses and relief valves existed, to protect the electrical and air systems.

(d) The ballast control system has the ability to override the electric controls altogether in the event of a power failure. This is accomplished by manually manipulating the control solenoid valve for the particular tank valve. Although this may be done in the absence of electrical power it is still necessary to have air pressure to activate the valve.

To perform this operation the front of the ballast control panel is removed exposing the various solenoid control valves. Plastic plugs covering an opening in the end of each solenoid is removed and threaded brass plugs are screwed in place. Through a threaded hole in the center of the brass plug a threaded brass rod is inserted. This rod is then screwed in to engage the solenoid valve and open the ballast valve and out to close the same. The action required between the open and close positions of the solenoid is small, approximately 1/10 in. This makes it difficult for the operator to know if a particular valve is open or closed at a glance and easy to make a mistake in the opening or closing of a ballast valve.

It should also be noted that the control solenoid valve is manually activated by the brass rod pushing the control valve to the open position. It spring returns to the closed position as the rod is removed.

Should the panel be powered it is possible for the manual controls to open a valve which is closed but not close a valve which is being held open electrically. In other words, the manual control system may only partially override the electrical control system. Of course it is possible to go down into the pontoon as well, and manually open or close each ballast valve with a wrench.

(e) Selection of the ballast valves to be opened is the responsibility of the operator using the system as designed. While such a system would be acceptable, it could be improved by the incorporation of alarms or interlocks to inhibit the selection of hazardous combinations of valve opening.

4.4.4 Ballast Tank Gauging

4.4.4.1 Operational Arrangements

Each ballast tank is provided with an individual depth of contents gauge of the mercury manometer type. These are mounted on panels in the ballast control room but not adjacent to the ballast control console. The layout may be somewhat confusing with starboard indicators on the port side of the control room and vice versa.

4.4.4.2 Indication of Operational Status

Each gauge is provided with a flow meter to indicate that the air is flowing through the system and therefore that the gauge reading is valid.

4.4.4.3 Common Mode Failure

The air supply to the tank gauging system is common with that to the ballast valve control console and has no standby source. Failure of the air supply to the gauges would render their readings invalid; however this should be apparent to the operator because all the flow meters would show no flow. Since the ballast valves would also spring shut under these circumstances, the tank contents should remain unchanged until the air supply can be restored and the system becomes operational again.

4.4.4.4 Controls, Alarms and Safeguards

(a) The only relevant control in the ballast tank gauging system is the one enabling the operator to purge the system periodically. Its frequency of use is a matter of operational procedure.

(b) There are no alarms associated with the gauging system. If the air supply to the ballast valve control console were to be provided with a failure alarm in accordance with current requirements, this would also indicate failure of the supply to the gauges.

(c) There are no safeguards built into the gauging system. Reliance is placed on the operating procedures to ensure that purging of the system is carried out at the requisite intervals, and that the flow indicators are checked before any readings are taken.

Table 4.1

Ballast Tank Loss Coefficients

		Loss Coeficient	Ballast Tank No.				
Tank No.			1	2 & 3	4	7	8 & 9
Horiz. Len.			274.97	232.32	194.32	154.32	119.32
Actual Len.		1.97×10^{-4}	299.21	255.46	219.00	182.54	134.63
Large Rad. Turns D/R of 3.12	45°	.2	15	14	10	10	8
	90°	.4	-	-	-	1	-
Sharp Rad. Turns D/R of 1.61	45°	3	2	-	-	-	-
	90°	75	2	1	2	3	1
Bell Mouths		.05	1	1	1	1	1
Butterfly Values		.03	3	3	3	3	3
Tee Connections		1.0	4	3	4	4	3
Restrictions		.30	1	1	1	1	1
Strainers		1.0	1	1	1	1	1
Expansions		.35	-	1	-	-	-
Total Minor Losses			11.05	9.15	9.75	10.9	7.6

Table 4.2

Ballast System Head Loss

System Configuration		System Head Loss (ft)												System Symbol	System Minor Loss Factor	(ft) Total System Length	(ft) Horizontal System Length
TANK NO 1	1 pump 1 tank	0.89	3.16	6.73	11.56	17.65	24.98	33.57	43.39	54.45	66.76	80.30	95.08	○	11.05	299.21	274.97
	2 pumps 1 tank	3.16	11.56	24.98	43.39	66.76	95.08	128.36	166.58	209.75	257.87	310.93	368.94	△			
TANK NO 2 & 3	1 pump 1 tank	0.74	2.66	5.65	8.71	14.83	21.00	28.20	36.46	45.75	56.09	67.47	79.89	○	9.15	255.46	232.32
	1 pump 2 tanks	0.21	0.74	1.56	2.66	4.02	5.65	7.55	9.71	12.14	14.83	17.78	20.[illegible]	□			
	2 pumps 1 tank	2.66	9.71	20.99	36.46	56.09	79.89	107.85	139.97	176.24	216.67	261.26	310.00	△			
TANK NO 4	1 pump 1 tank	0.72	2.56	5.46	9.34	14.31	20.26	27.22	35.19	44.16	54.14	65.13	77.11	○	9.75	219.00	194.32
	2 pumps 1 tank	2.56	9.38	20.26	35.20	54.14	77.11	104.10	135.10	170.12	209.14	252.18	299.23	△			
TANK NO 7	1 pump 1 tank	0.72	2.55	5.44	9.34	14.26	20.19	27.12	35.06	44.00	53.94	64.88	76.83	○	10.9	182.54	154.32
	2 pumps 1 tank	2.55	9.34	20.19	35.06	53.94	76.83	103.71	134.60	169.48	208.36	251.24	298.11	△			
TANK NO 8 & 9	1 pump 1 tank	0.51	1.82	3.87	6.65	10.15	14.37	19.30	24.95	31.31	38.39	46.17	54.67	○	7.6	134.63	119.32
	1 pump 2 tanks	0.15	0.51	1.07	1.82	2.75	3.87	5.17	6.65	8.31	10.15	12.17	14.37	□			
	2 pumps 1 tank	1.817	6.65	14.37	24.95	38.39	54.67	73.81	95.79	120.61	148.20	178.79	212.15	△			
Flow Rate	ft^3/sec	0.577	1.114	1.671	2.228	2.785	3.342	3.899	4.456	5.013	5.510	6.127	6.684				
	US gal/min	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00				

Table 4.2A

Ballast System Head Loss Including Velocity Terms

System Configuration		System Head Loss (ft.)												Sys. Sym.	System Minor Loss Factor	(ft.) Total System Length	(ft.) Horizontal System Length
TANK NO 1	1 pump 1 tank	0.93	3.32	7.09	12.19	18.64	26.41	35.51	45.92	57.66	70.63	85.09	100.78	○	11.05	299.21	214.97
	2 pumps 1 tank	3.20	11.72	25.34	44.02	67.75	96.51	130.30	169.11	212.96	261.74	315.72	374.64	△			
TANK NO 2 & 3	1 pump 1 tank	0.78	2.82	6.01	9.34	15.82	22.43	30.14	38.99	48.96	59.96	72.26	85.59	○	9.15	255.46	232.32
	1 pump 2 tanks	0.25	0.90	1.92	3.29	5.01	7.08	9.49	12.24	15.35	18.70	22.57	26.69	□			
	2 pumps 1 tank	2.70	9.87	21.35	37.09	57.08	81.32	109.79	142.50	179.45	220.54	266.05	315.70	△			
TANK NO 4	1 pump 1 tank	0.76	2.72	5.82	9.97	15.30	21.69	29.16	37.72	47.37	58.01	69.92	82.81	○	9.75	219.00	194.32
	2 pumps 1 tank	2.60	9.54	20.62	35.83	55.13	78.54	106.04	137.63	173.33	213.01	256.97	304.93	△			
TANK NO 7	1 pump 1 tank	0.76	2.71	5.80	9.97	15.25	21.62	29.06	37.59	47.21	57.81	69.67	82.53	○	10.9	182.54	154.32
	2 pumps 1 tank	2.59	9.50	20.55	35.69	54.93	78.26	105.65	137.13	172.69	212.23	256.03	303.81	△			
TANK NO 8 & 9	1 pump 1 tank	0.55	1.98	4.23	7.28	11.14	15.80	21.24	27.48	34.52	42.26	50.96	60.37	○	7.6	134.63	119.32
	1 pump 2 tanks	0.19	0.67	1.43	2.45	3.74	5.30	7.11	9.18	11.52	14.02	16.96	20.07	□			
	2 pumps 1 tank	1.86	6.81	14.73	25.58	39.38	56.10	75.75	98.32	123.82	152.07	183.58	217.85	△			
VELOCITY HEAD (FEET)		0.042	0.158	0.356	0.633	0.989	1.425	1.939	2.532	3.205	3.872	4.788	5.69				
FLOW RATE	Ft^3/sec	0.577	1.114	1.671	2.228	2.785	3.342	3.899	4.456	5.013	5.510	6.127	6.68				
	US gal/min	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00				

Table 4.3

Emergency Switchboard

Systems	Location	Capacity
1. Lifeboat No. 1	Upper deck fwd.	7.5 hp
2. Rescue boat	Upper deck aft. port	7.5 hp
3. Lifeboat No. 2	Upper deck aft. stbd.	7.5 hp
4. Stbd. ballast pump No. 6	Stbd. prop. room	125 hp
5. Emergency fire pump	Mud pump room	40 hp
6. Drawworks motor and rotary unit motor supply fan		30 hp
7. Port ballast pump No. 5	Port prop. room	135 hp
8. B.O.P. equipment room and elect. room supply fan		20 hp
9. Hydraulic power pack for winches Nos. 1 to 12		12 X 33 hp
10. Emergency diesel engine		1510 KVA
11. Emergency generator		
12. Ballast control console		
13. Sliding door sys. section panel		
14. Quarters light dist. panel		
15. Stbd. pump room light panel		
16. Port pumproom light panel		
17. Emergency vent. fan stop cabinet	Electric room	
18. Diver's control house	Celler deck stbd.	125 hp
19. Habitat	Celler deck stbd.	45 KWA

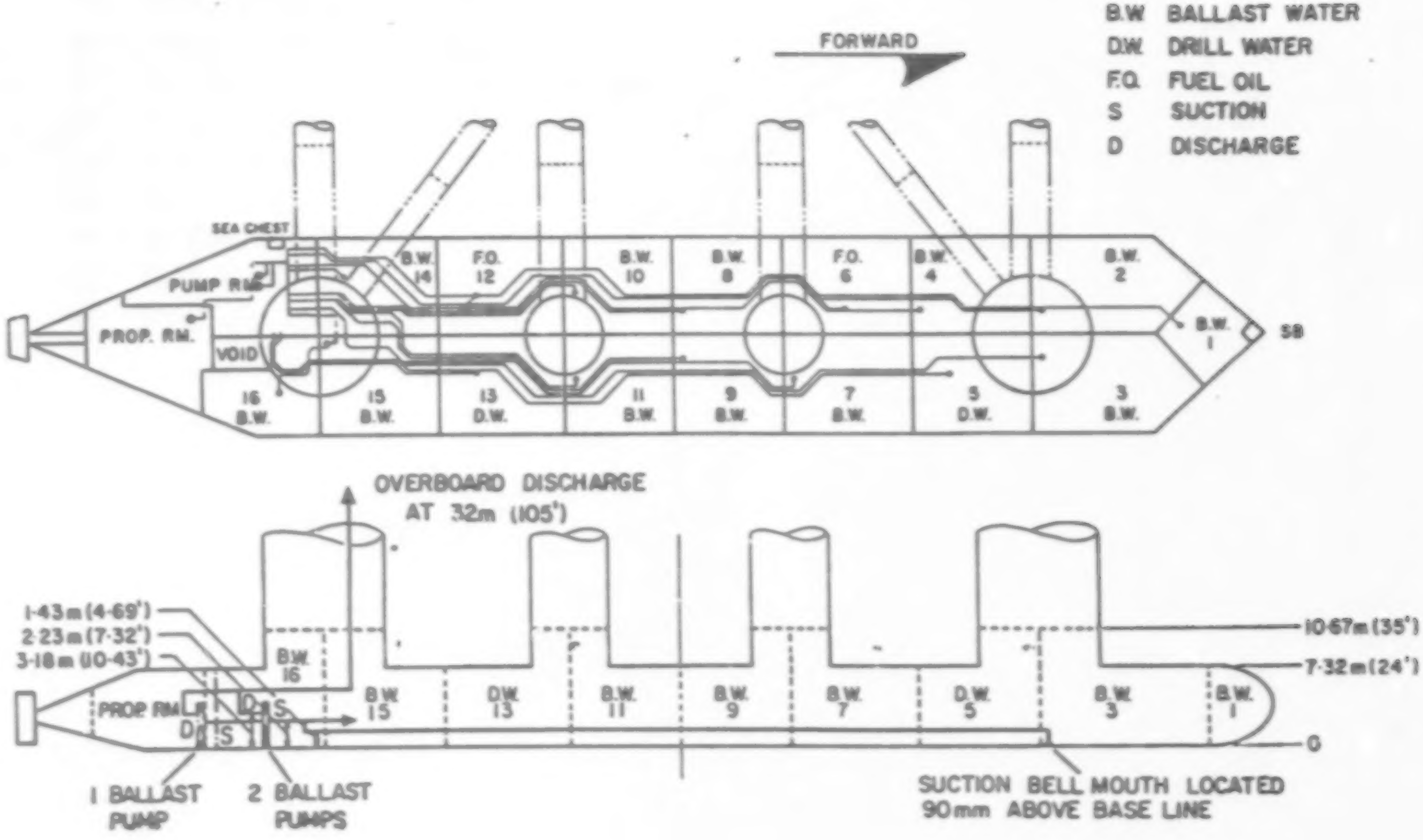
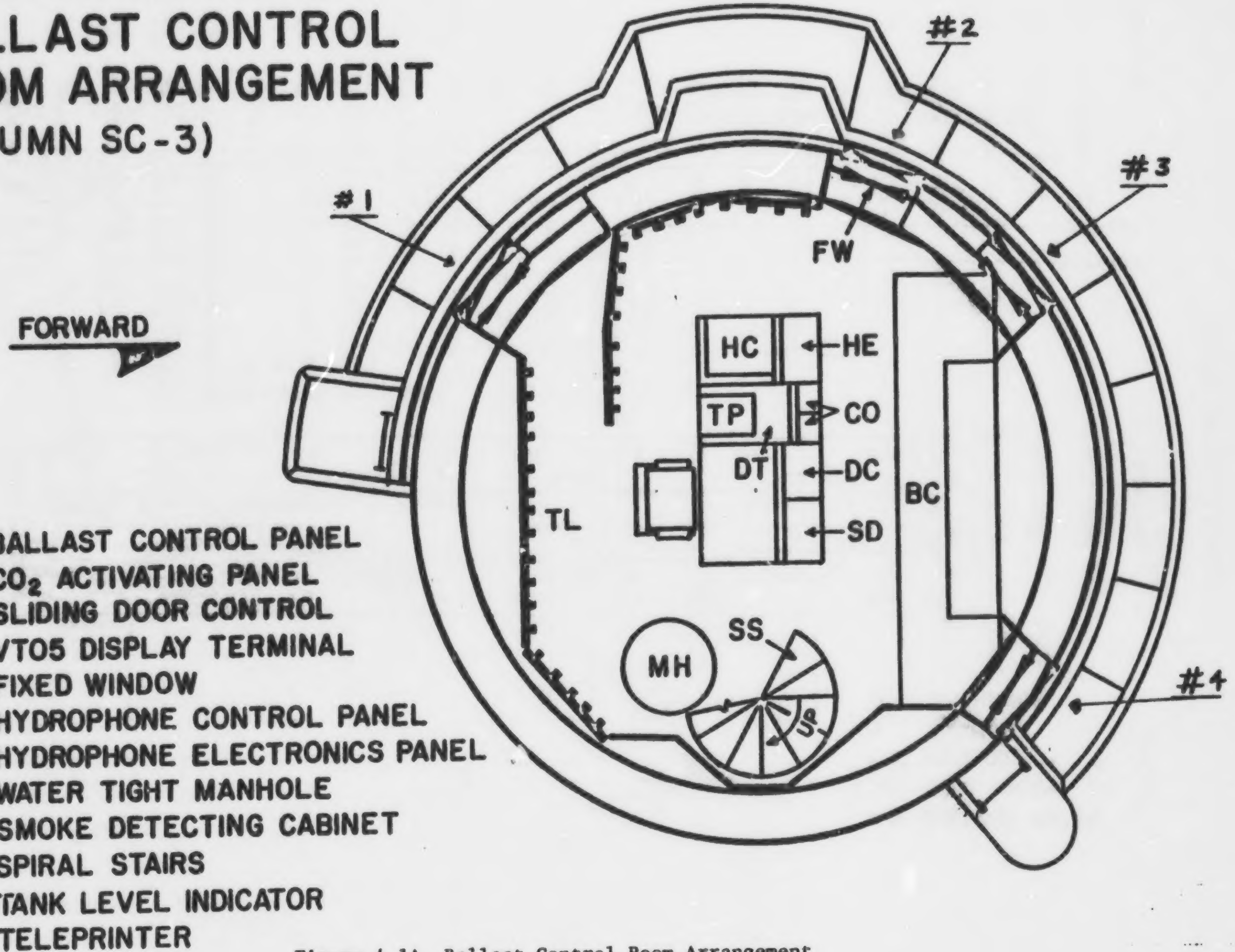

B.W BALLAST WATER
D.W DRILL WATER
F.O. FUEL OIL
S SUCTION
D DISCHARGE
FORWARD
SEA CHEST
PUMP RM.
PROP. RM.
VOID
B.W. 14
F.O. 12
B.W. 10
B.W. 8
F.O. 6
B.W. 4
B.W. 2
B.W. 1
SB
16 B.W.
15 B.W.
13 D.W.
11 B.W.
9 B.W.
7 B.W.
5 D.W.
3 B.W.
OVERBOARD DISCHARGE AT 32m (105')
1·43m (4·69')
2·23m (7·32')
3·18m (10·43')
B.W. 16
PROP. RM.
D
S
B.W. 15
D.W. 13
B.W. 11
B.W. 9
B.W. 7
D.W. 5
B.W. 3
B.W. 1
10·67m (35')
7·32m (24')
0
1 BALLAST PUMP
2 BALLAST PUMPS
SUCTION BELL MOUTH LOCATED 90mm ABOVE BASE LINE

Figure 4.1 OCEAN RANGER Lower Hull Ballast Tanks and Ballast Pump Configuration

OCEAN RANGER
BALLAST CONTROL ROOM ARRANGEMENT
(COLUMN SC-3)


FORWARD
#1
#2
#3
#4
FW
HC
HE
TP
CO
DT
DC
SD
BC
TL
MH
SS
Up

BC	BALLAST CONTROL PANEL
CO	CO_2 ACTIVATING PANEL
DC	SLIDING DOOR CONTROL
DT	VTO5 DISPLAY TERMINAL
FW	FIXED WINDOW
HC	HYDROPHONE CONTROL PANEL
HE	HYDROPHONE ELECTRONICS PANEL
MH	WATER TIGHT MANHOLE
SD	SMOKE DETECTING CABINET
SS	SPIRAL STAIRS
TL	TANK LEVEL INDICATOR
TP	TELEPRINTER

Figure 4.1A Ballast Control Room Arrangement

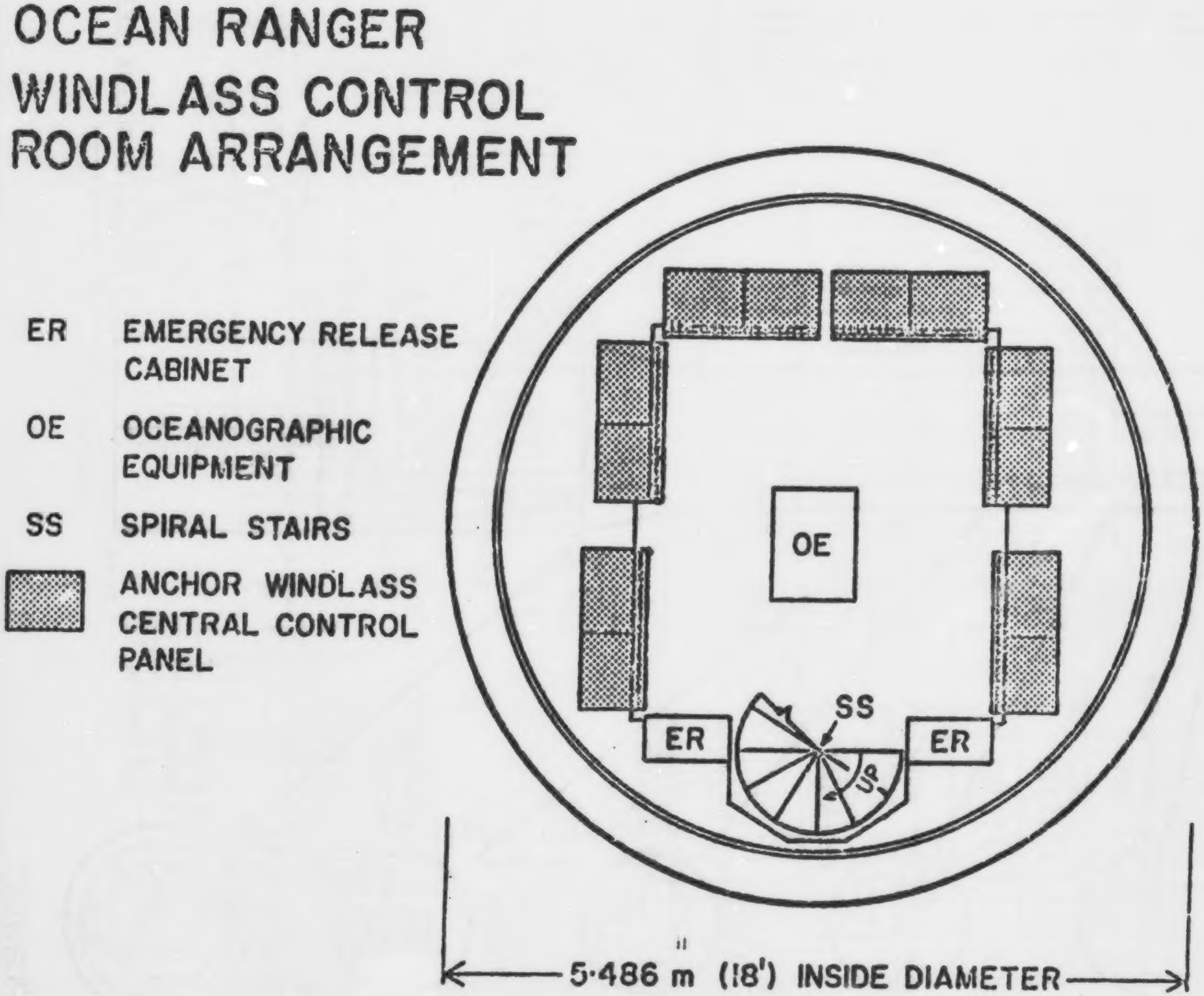

OCEAN RANGER
WINDLASS CONTROL
ROOM ARRANGEMENT
ER EMERGENCY RELEASE CABINET
OE OCEANOGRAPHIC EQUIPMENT
SS SPIRAL STAIRS
▨ ANCHOR WINDLASS CENTRAL CONTROL PANEL
OE
SS
ER
ER
UP
5·486 m (18') INSIDE DIAMETER

Figure 4.1B Windlass Control Room Arrangement

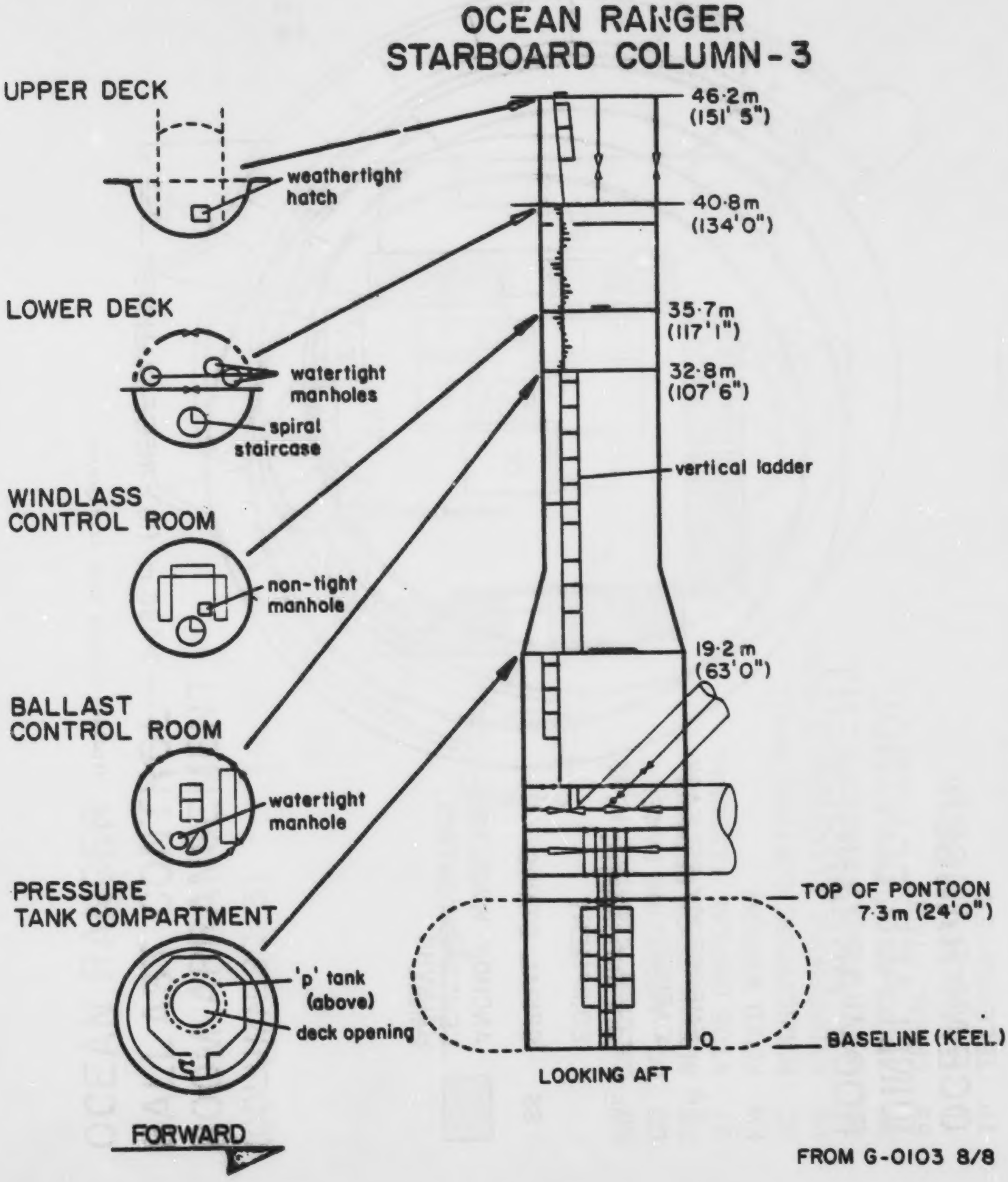
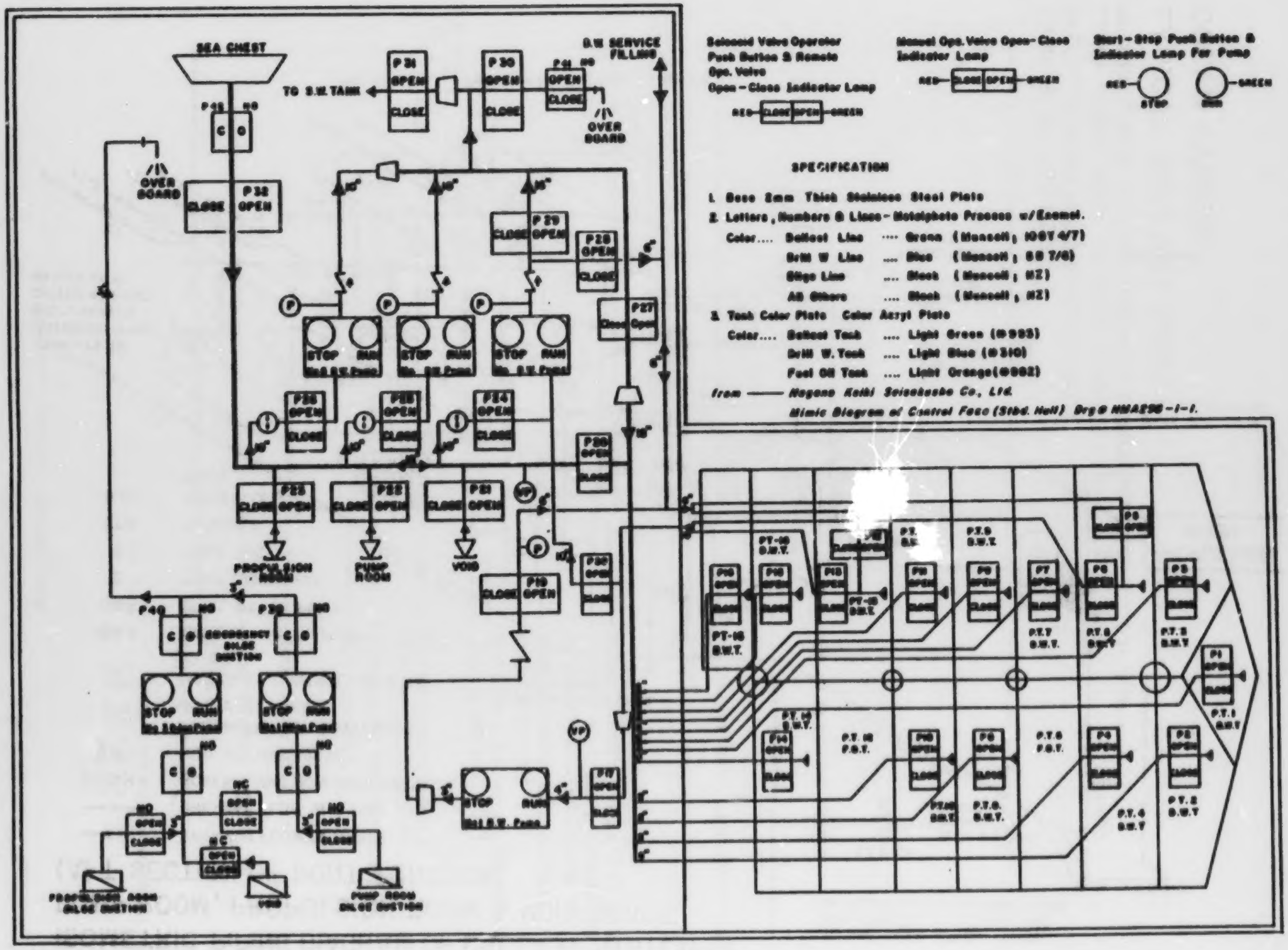

OCEAN RANGER
STARBOARD COLUMN-3
UPPER DECK
weathertight hatch
LOWER DECK
watertight manholes
spiral staircase
WINDLASS CONTROL ROOM
non-tight manhole
BALLAST CONTROL ROOM
watertight manhole
PRESSURE TANK COMPARTMENT
'p' tank (above)
deck opening
FORWARD
46·2m (151' 5")
40·8m (134'0")
35·7m (117'1")
32·8m (107'6")
vertical ladder
19·2m (63'0")
TOP OF PONTOON 7·3m (24'0")
0
BASELINE (KEEL)
LOOKING AFT
FROM G-0103 8/8

Figure 4.1C Starboard Column 3


SEA CHEST
TO S.W. TANK
P 31 OPEN CLOSE
P 30 OPEN CLOSE
P 41 NO OPEN CLOSE
D.W SERVICE FILLING
OVER BOARD
P 45 NO C O
OVER BOARD
P 32 CLOSE OPEN
P 29 CLOSE OPEN
P 28 OPEN CLOSE
P 27 Close Open
STOP RUN
P 26 OPEN CLOSE
P 25 OPEN CLOSE
P 24 OPEN CLOSE
P 20 OPEN CLOSE
P 23 CLOSE OPEN
P 22 CLOSE OPEN
P 21 CLOSE OPEN
PROPULSION ROOM
PUMP ROOM
VOID
VP
P 19 CLOSE OPEN
P 40 NO C O
P 39 NO C O
EMERGENCY BILGE SUCTION
NO
NC OPEN CLOSE
NO OPEN CLOSE
NC OPEN CLOSE
NO OPEN CLOSE
PROPULSION ROOM BILGE SUCTION
VOID
PUMP ROOM BILGE SUCTION
P 17 OPEN CLOSE
STOP RUN
PT-16 D.W.T.
PT-15 D.W.T.
PT-13 D.W.T.
P.T. 11 B.W.T.
P.T. 9 D.W.T.
P.T. 7 D.W.T.
P.T. 5 B.W.T.
P.T. 3 B.W.T.
P1 OPEN CLOSE
P.T. 1 B.W.T.
P.T. 14 D.W.T.
P.T. 12 F.O.T.
P.T. 10 B.W.T.
P.T. 8 F.O.T.
P.T. 6 B.W.T.
P.T. 4 B.W.T.
P.T. 2 B.W.T.

Solenoid Valve Operator Push Button & Remote Ope. Valve Open-Close Indicator Lamp

RED CLOSE OPEN GREEN

Manual Ope. Valve Open-Close Indicator Lamp

RED CLOSE OPEN GREEN

Start-Stop Push Button & Indicator Lamp For Pump

RED STOP
RUN GREEN

SPECIFICATION

1. Base 2mm Thick Stainless Steel Plate
2. Letters, Numbers & Lines - Metalphoto Process w/Enamel.
   Color.... Ballast Line .... Green (Munsell; 10GY 4/7)
   Drill W Line .... Blue (Munsell; 5B 7/6)
   Bilge Line .... Black (Munsell; N2)
   All Others .... Black (Munsell, N2)
3. Tank Color Plate Color Acryl Plate
   Color.... Ballast Tank .... Light Green (#923)
   Drill W. Tank .... Light Blue (#310)
   Fuel Oil Tank .... Light Orange(#902)

from —— Nagano Keiki Seisakusho Co., Ltd.
Mimic Diagram of Control Face (Stbd. Hull) Drg# NMA298-1-1.

Figure 4.2 Port Mimic Panel

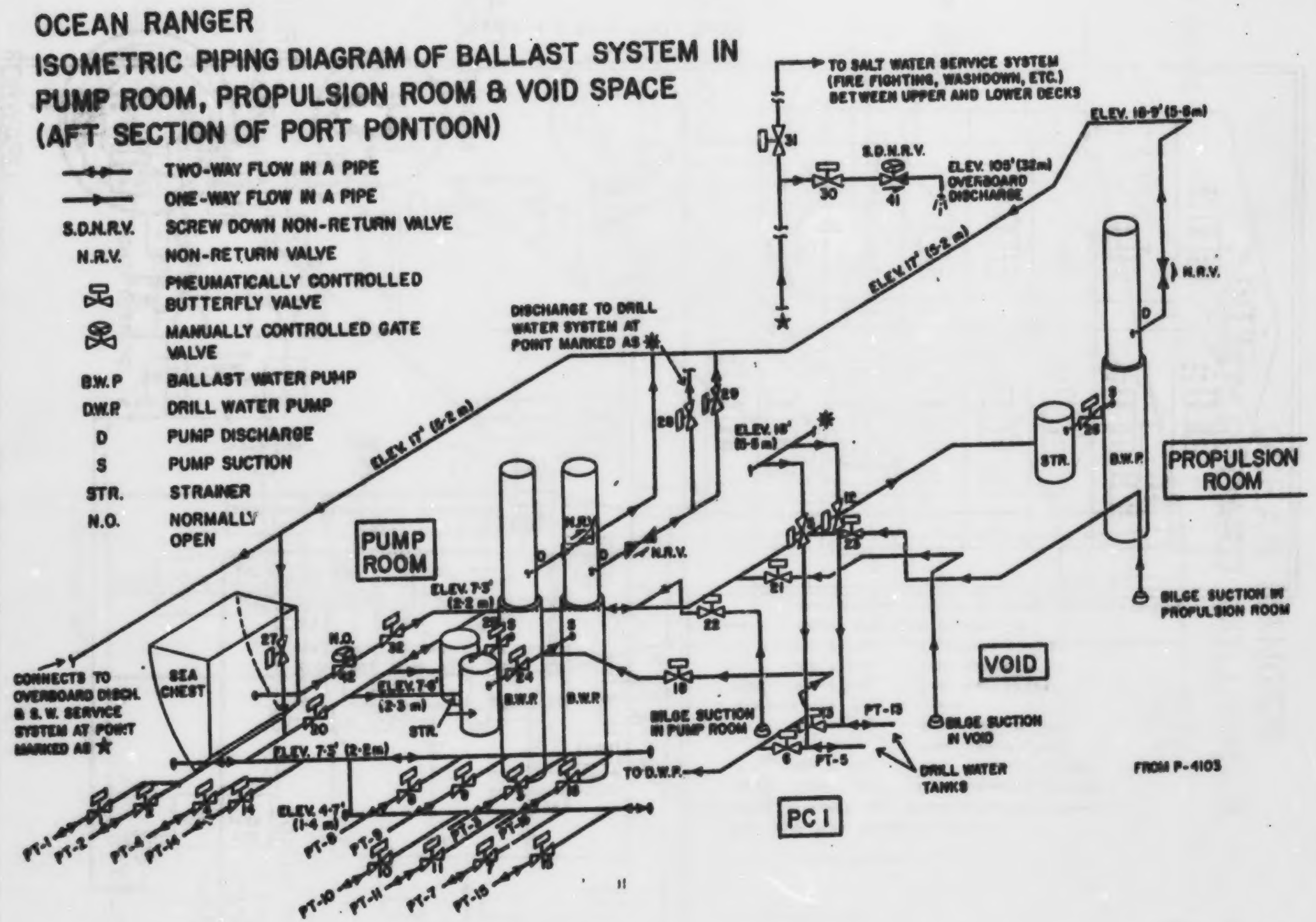

OCEAN RANGER
ISOMETRIC PIPING DIAGRAM OF BALLAST SYSTEM IN PUMP ROOM, PROPULSION ROOM & VOID SPACE (AFT SECTION OF PORT PONTOON)
TWO-WAY FLOW IN A PIPE
ONE-WAY FLOW IN A PIPE
S.D.N.R.V. SCREW DOWN NON-RETURN VALVE
N.R.V. NON-RETURN VALVE
PNEUMATICALLY CONTROLLED BUTTERFLY VALVE
MANUALLY CONTROLLED GATE VALVE
B.W.P BALLAST WATER PUMP
D.W.P DRILL WATER PUMP
D PUMP DISCHARGE
S PUMP SUCTION
STR. STRAINER
N.O. NORMALLY OPEN
TO SALT WATER SERVICE SYSTEM (FIRE FIGHTING, WASHDOWN, ETC.) BETWEEN UPPER AND LOWER DECKS
31
30
S.D.N.R.V.
41
ELEV. 105' (32m) OVERBOARD DISCHARGE
ELEV. 18-9' (5-8m)
ELEV. 17' (5-2 m)
N.R.V.
D
DISCHARGE TO DRILL WATER SYSTEM AT POINT MARKED AS ✱
28
29
ELEV. 18' (5-5 m)
12
23
21
22
19
STR.
S
26
B.W.P.
PROPULSION ROOM
BILGE SUCTION IN PROPULSION ROOM
VOID
BILGE SUCTION IN VOID
PT-13
PT-5
6
DRILL WATER TANKS
FROM P-4103
BILGE SUCTION IN PUMP ROOM
TO D.W.P.
PC I
PUMP ROOM
N.R.V.
ELEV. 7-5' (2-2 m)
S
D
B.W.P
B.W.P
24
STR.
ELEV. 7-6' (2-3 m)
N.O.
42
32
27
20
SEA CHEST
CONNECTS TO OVERBOARD DISCH. & S. W. SERVICE SYSTEM AT POINT MARKED AS ★
ELEV. 7-5' (2-2m)
ELEV. 4-7' (1-4 m)
PT-1
PT-2
PT-4
PT-14
PT-8
PT-9
PT-3
PT-16
PT-10
PT-11
PT-7
PT-15
10
11
7
15

Figure 4.3 Isometric Piping Diagram

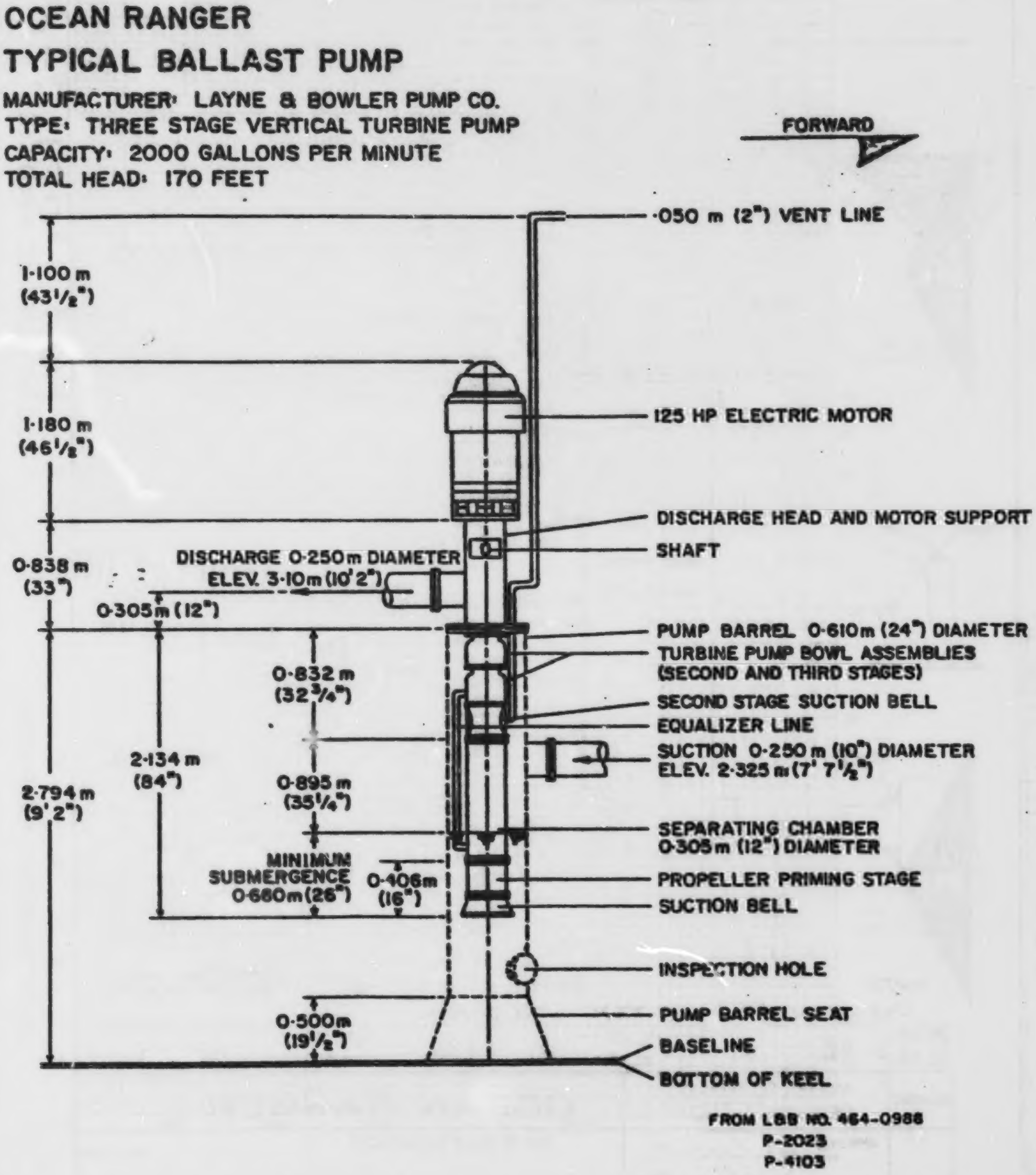
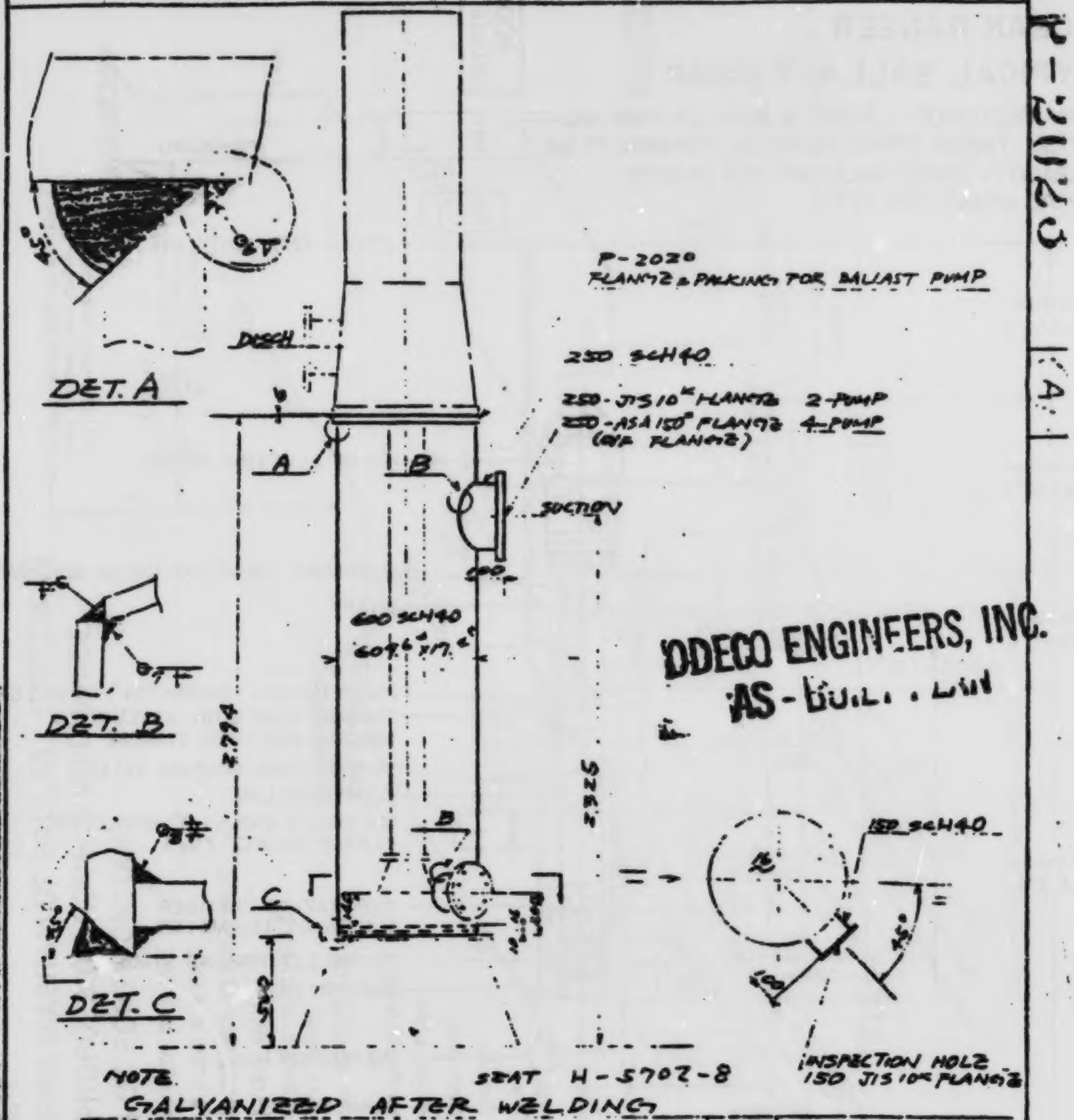

OCEAN RANGER
TYPICAL BALLAST PUMP
MANUFACTURER: LAYNE & BOWLER PUMP CO.
TYPE: THREE STAGE VERTICAL TURBINE PUMP
CAPACITY: 2000 GALLONS PER MINUTE
TOTAL HEAD: 170 FEET
FORWARD
·050 m (2") VENT LINE
1·100 m (43½")
1·180 m (46½")
125 HP ELECTRIC MOTOR
DISCHARGE HEAD AND MOTOR SUPPORT
SHAFT
0·838 m (33")
DISCHARGE 0·250 m DIAMETER ELEV. 3·10 m (10'2")
0·305 m (12")
PUMP BARREL 0·610 m (24") DIAMETER
TURBINE PUMP BOWL ASSEMBLIES (SECOND AND THIRD STAGES)
0·832 m (32¾")
SECOND STAGE SUCTION BELL
EQUALIZER LINE
SUCTION 0·250 m (10") DIAMETER ELEV. 2·325 m (7' 7½")
2·134 m (84")
2·794 m (9' 2")
0·895 m (35¼")
SEPARATING CHAMBER 0·305 m (12") DIAMETER
MINIMUM SUBMERGENCE 0·660 m (26")
0·406 m (16")
PROPELLER PRIMING STAGE
SUCTION BELL
INSPECTION HOLE
0·500 m (19½")
PUMP BARREL SEAT
BASELINE
BOTTOM OF KEEL
FROM LBB NO. 464-0988
P-2023
P-4103

Figure 4.4 Typical Ballast Pump

PLAN RECORD | 1. REVISION A JULY 3 '74 AS REQUESTED BY MAKER'S RESIDENT SURVEYOR


P-2020
FLANGE & PACKING FOR BALLAST PUMP
DISCH
DET. A
250 SCH40
250-JIS10K FLANGE 2-PUMP
250-ASA150# FLANGE 4-PUMP
(O/F FLANGE)
A
B
SUCTION
600 SCH40
609.6φ×17.5t
DET. B
2794
2325
B
C
150 SCH40
45°
DET. C
INSPECTION HOLE
150 JIS10K FLANGE

ODECO ENGINEERS, INC.
AS-BUILT

NOTE.
GALVANIZED AFTER WELDING
SEAT H-5702-8

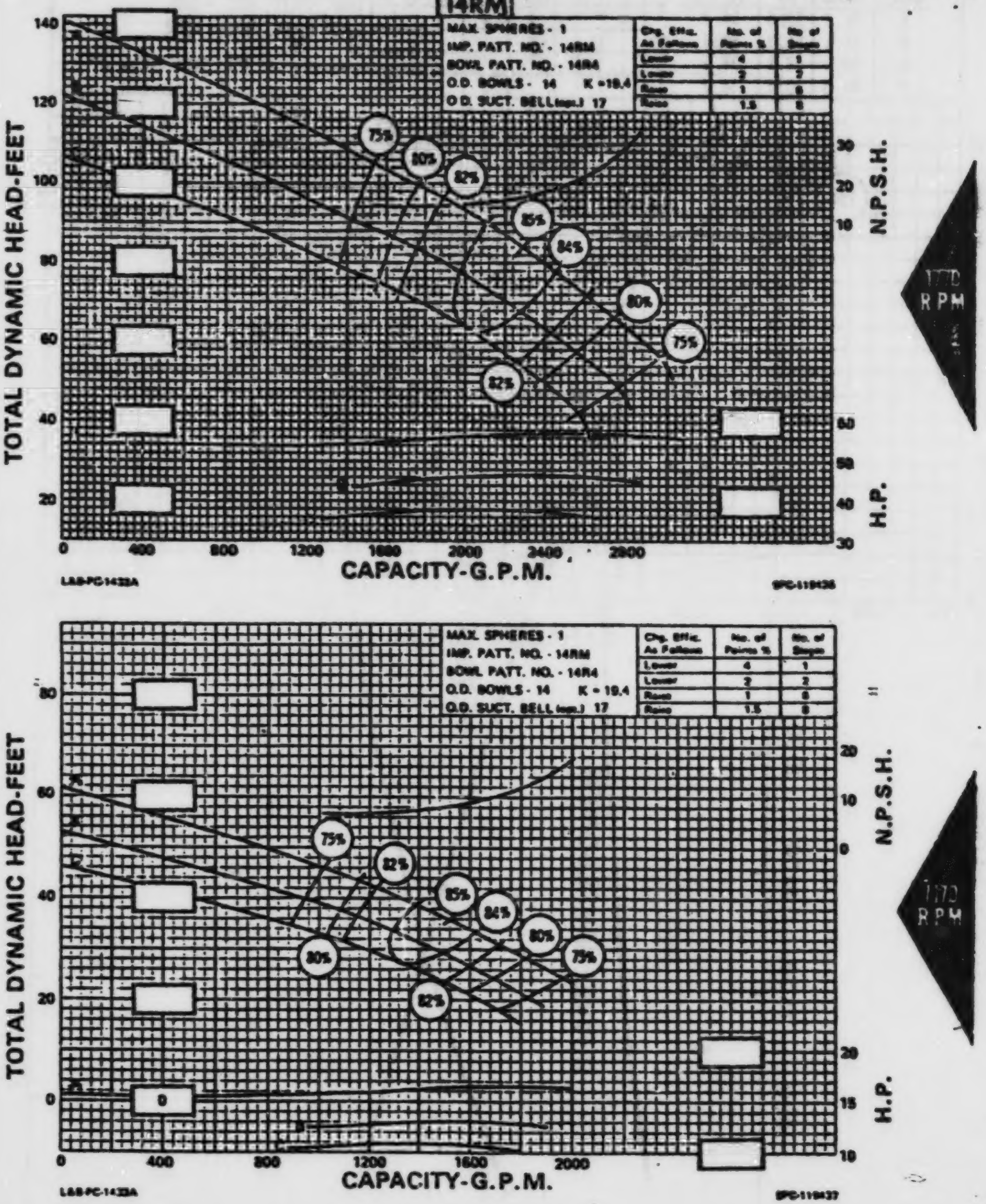
[illegible]	艤 内	[illegible]	生 技	[illegible]	6

MARINE OUTFITTING DESIGNING SECTION	OCEAN RANGER
APPROVED S. Shii...	BALLAST PUMP BARREL
CHECKED S. ARIMA	
DRAWN K. MASUDA	
SCALE 1/25	
ORDER 24... ITEM	DRAWING NO. ...-2023 R A

Figure 4.5 Ballast Pump Barrel

Verti-Line PUMP DATED JULY 1972

14RM



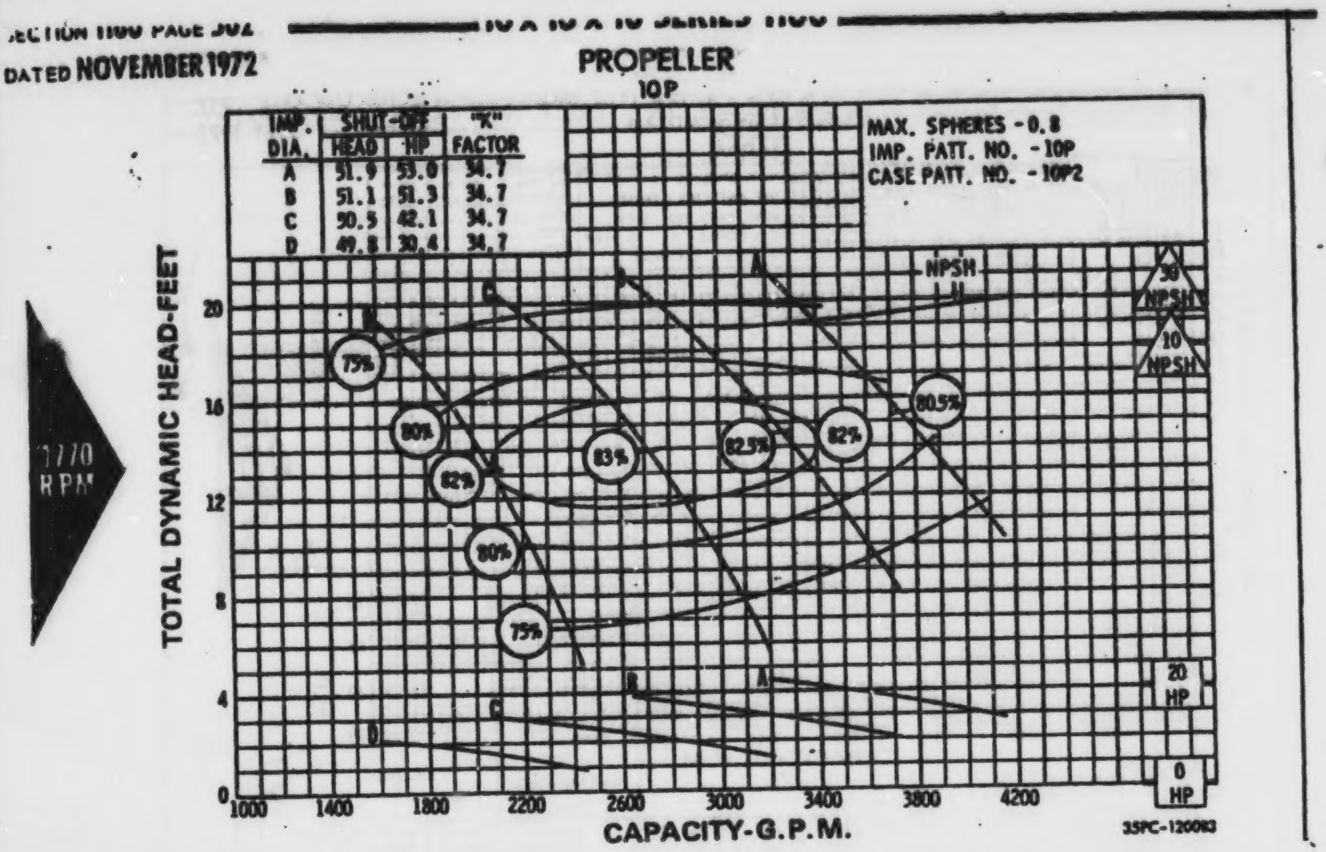
LAYNE AND BOWLER
A SUBSIDIARY OF THE AURORA PUMP
UNIT OF GENERAL SIGNAL
[illegible]

NUMBER OF STAGES REQUIRED FOR APPLICATION.

STANDARD CURVE ILLUSTRATES SINGLE STAGE PERFORMANCE ONLY.

Figure 4.6 Pump Capacity Curves

CURVES



IMP. DIA.	SHUT-OFF HEAD	SHUT-OFF HP	"K" FACTOR
A	51.9	53.0	34.7
B	51.1	51.3	34.7
C	50.5	42.1	34.7
D	49.8	30.4	34.7

Figure 4.7 Pump Capacity Curves

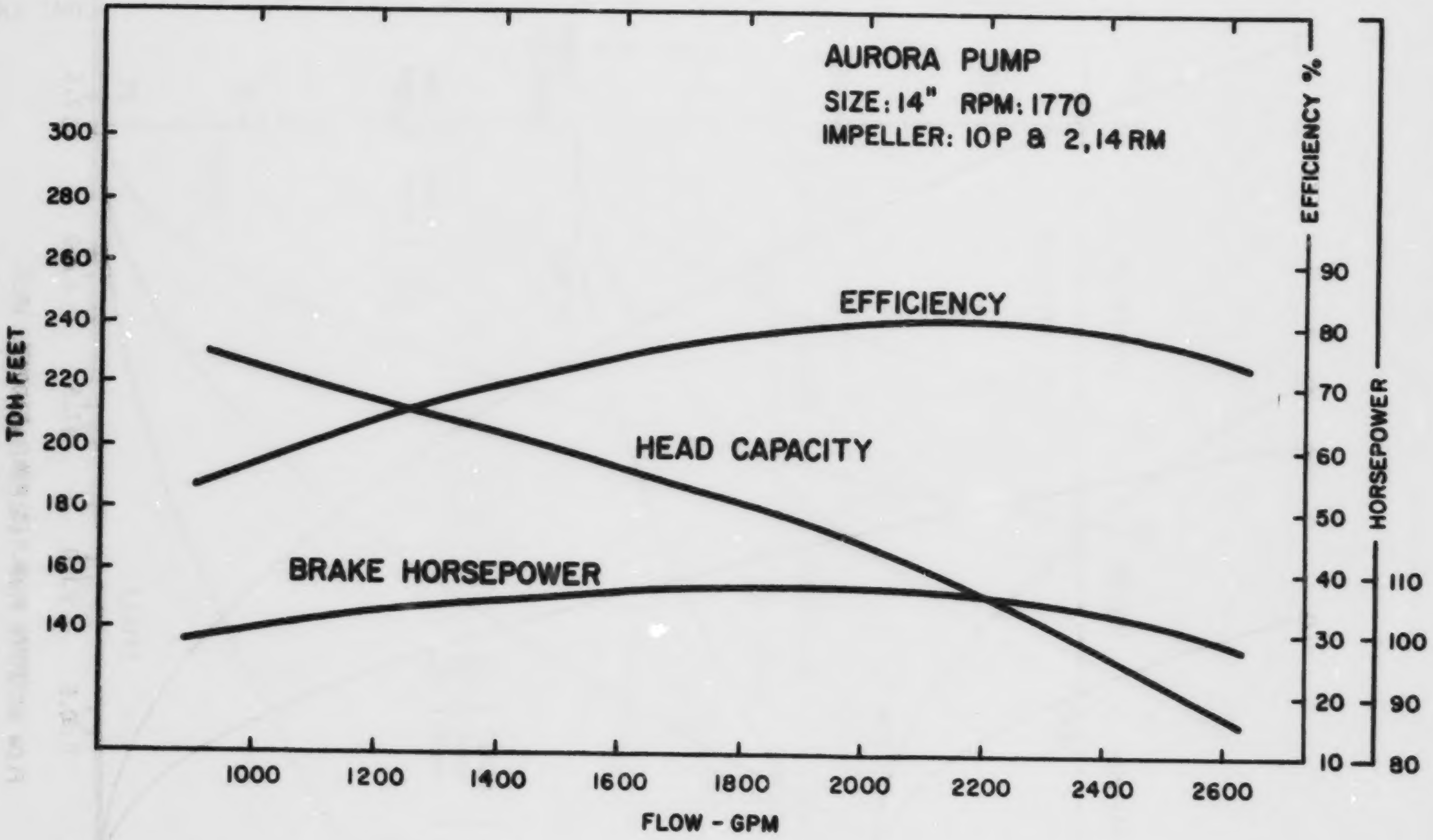


Figure 4.8 Pump Capacity Curves

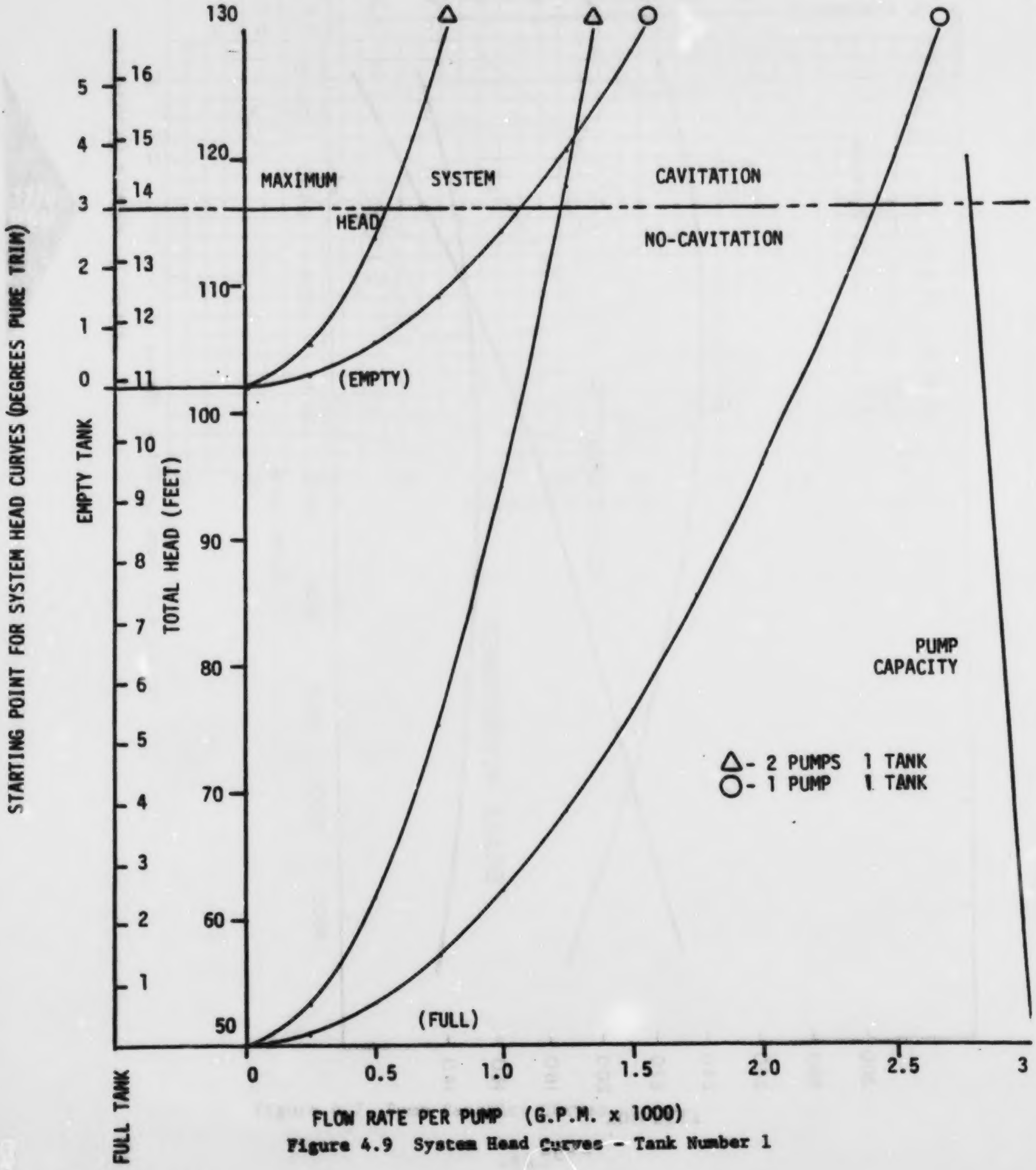


Figure 4.9 System Head Curves - Tank Number 1

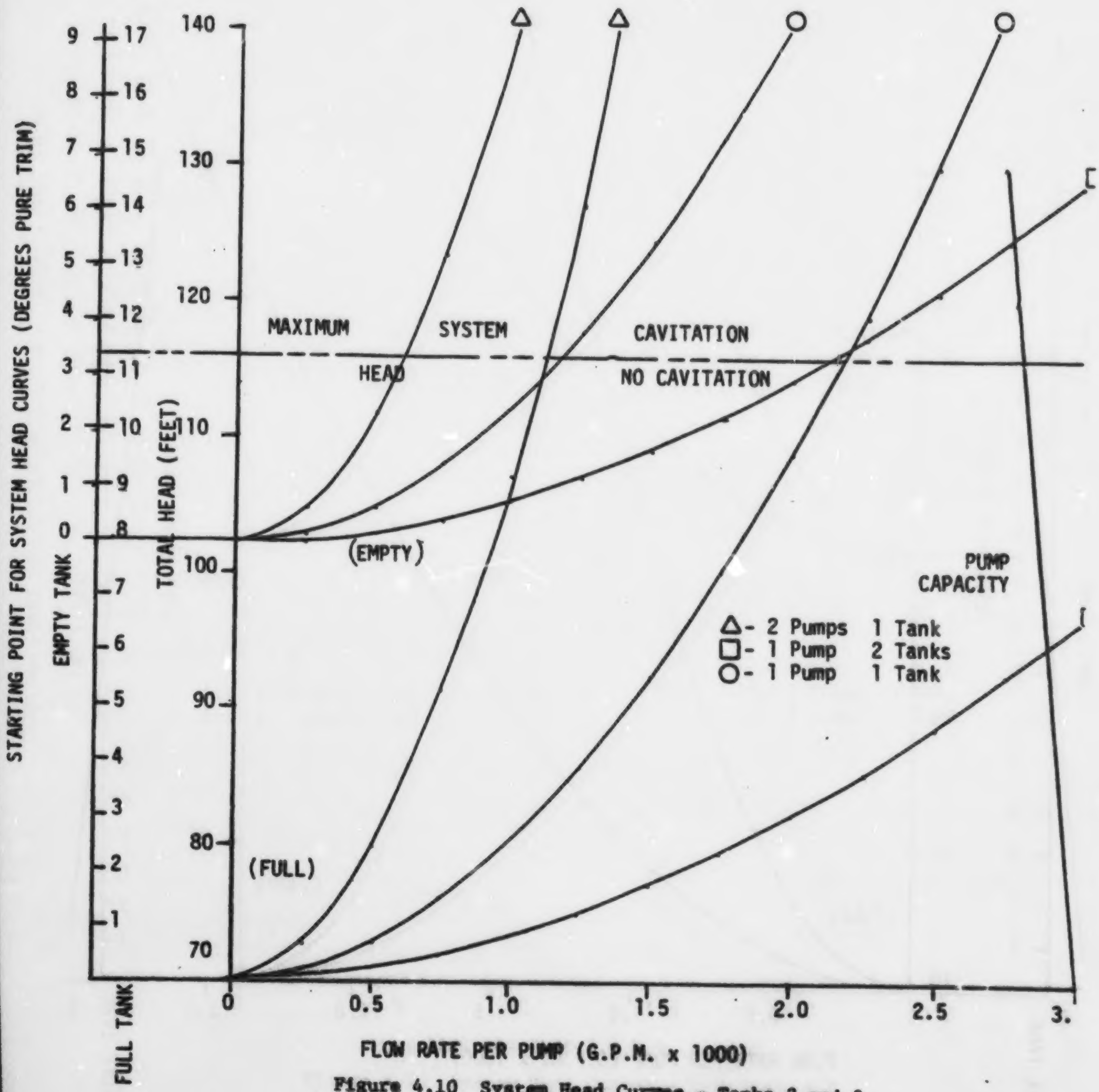


Figure 4.10 System Head Curves - Tanks 2 and 3

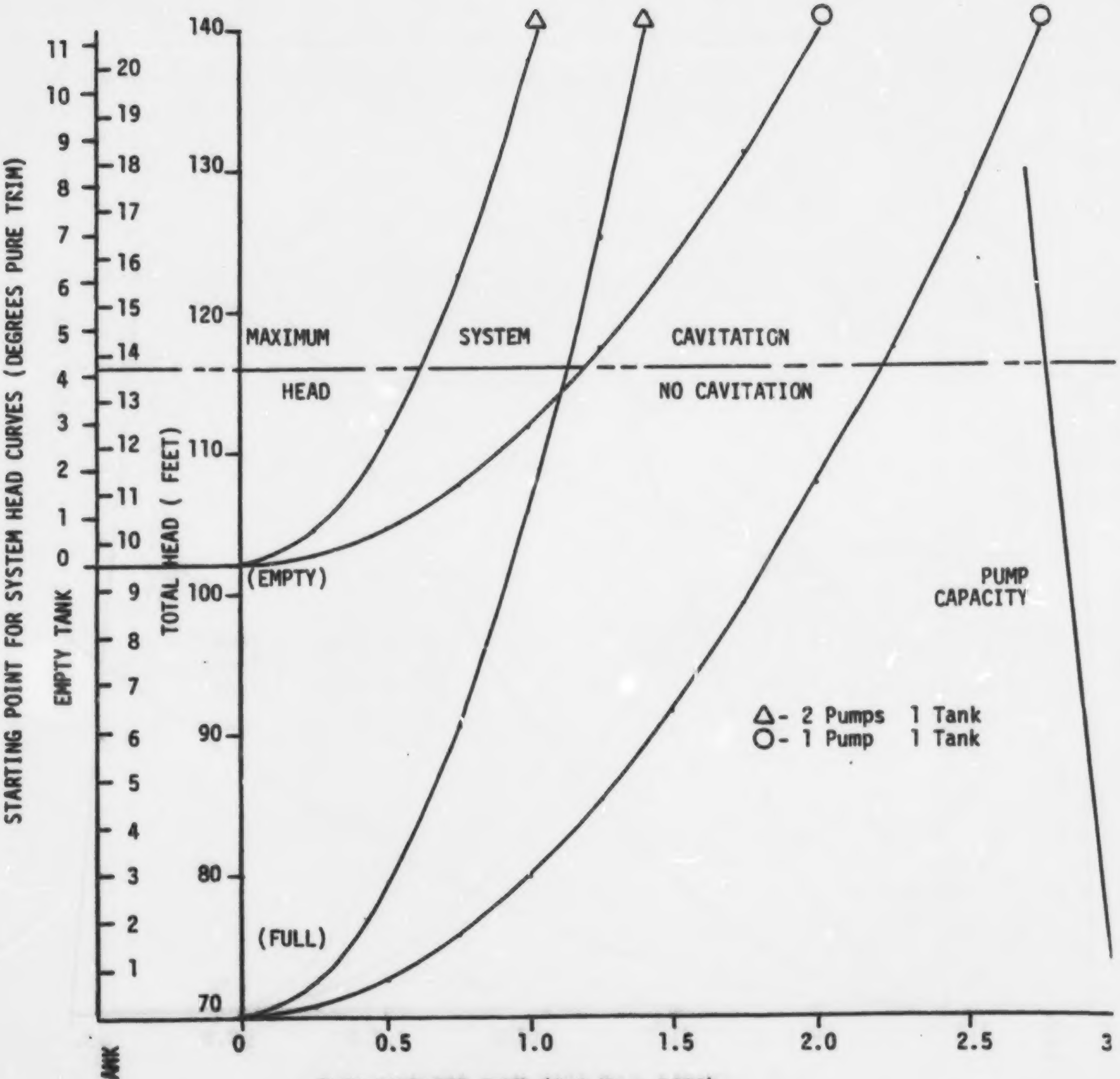


Figure 4.11 System Head Curves - Tank Number 4

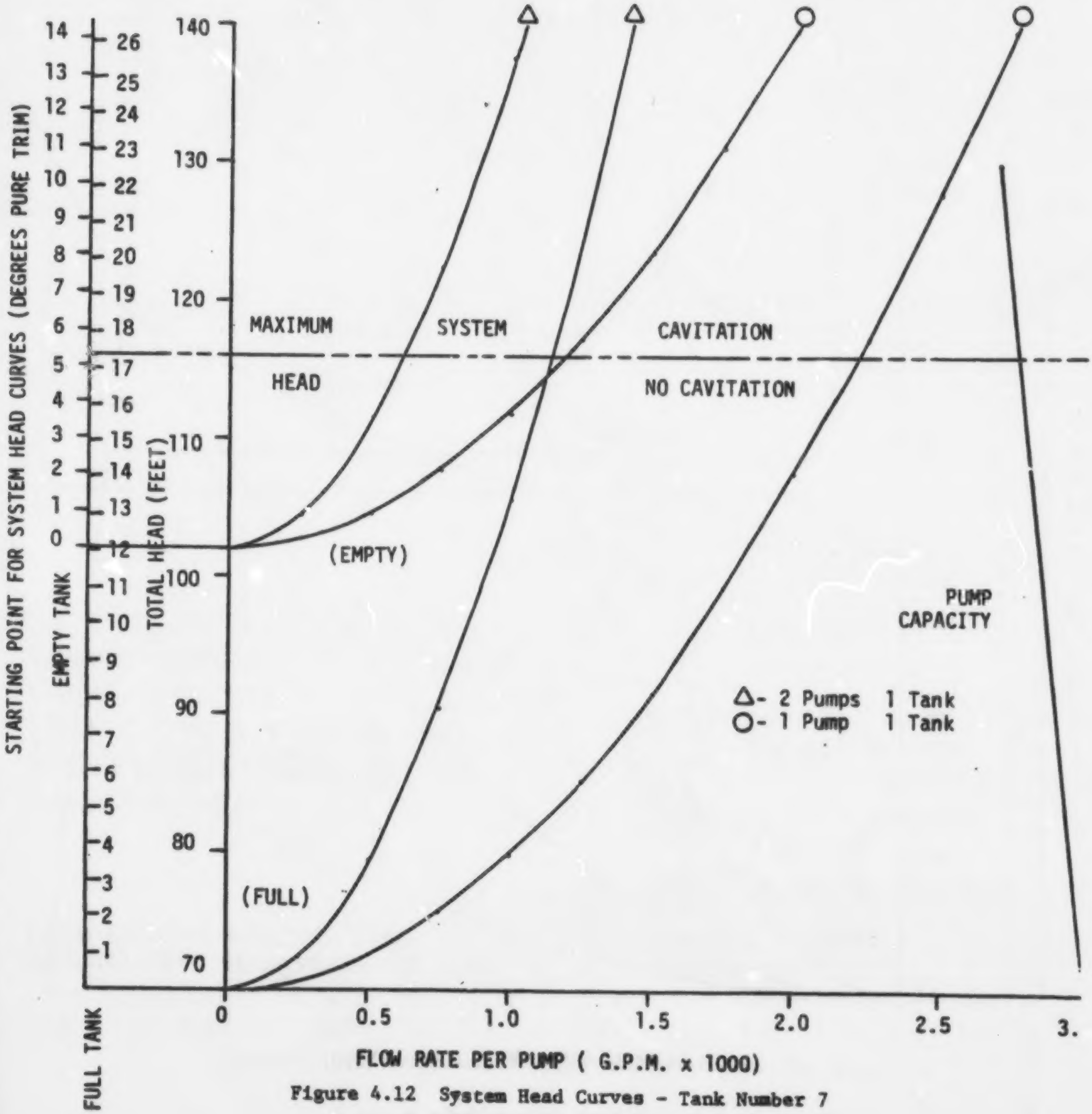


Figure 4.12 System Head Curves - Tank Number 7

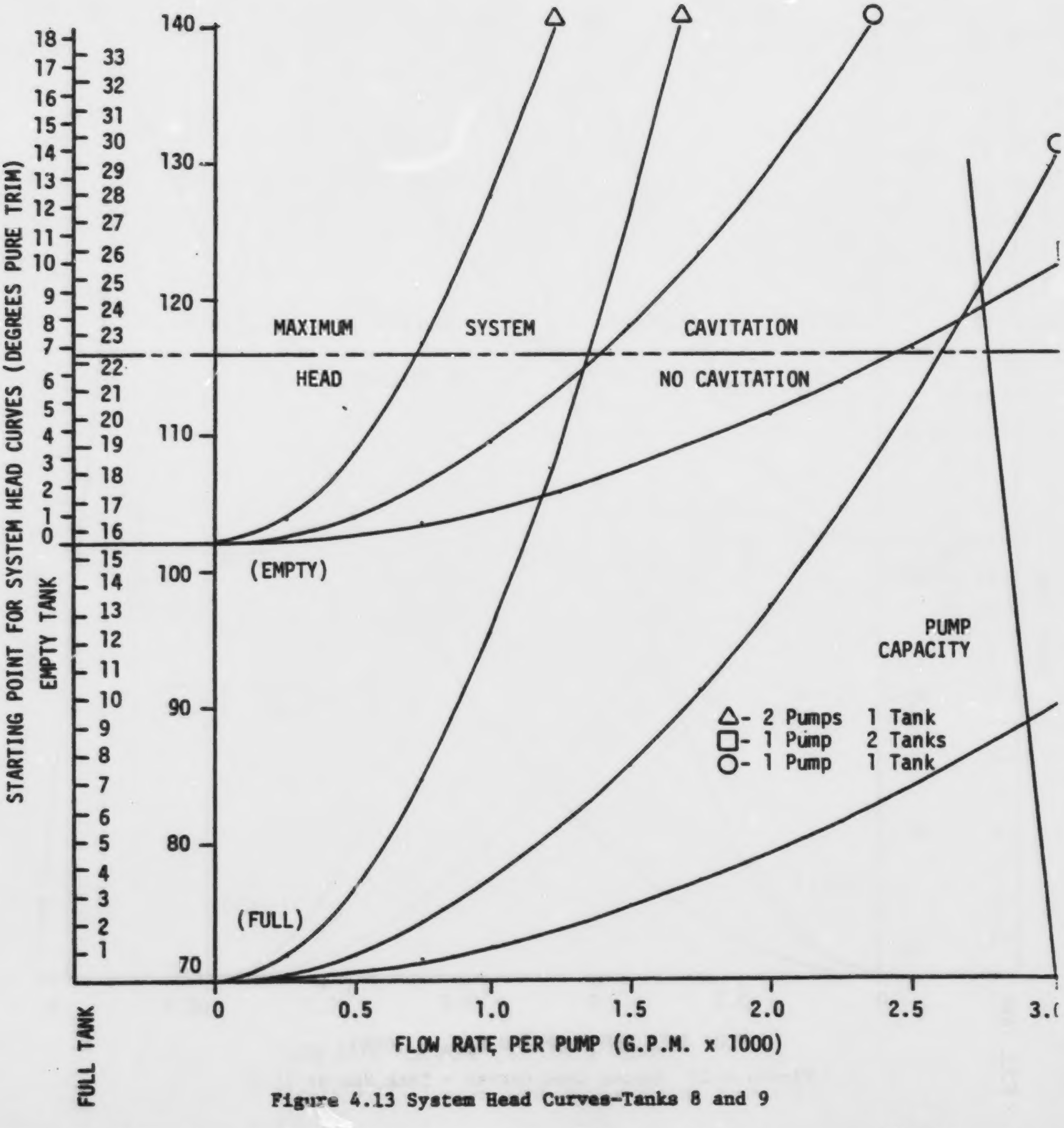


Figure 4.13 System Head Curves-Tanks 8 and 9

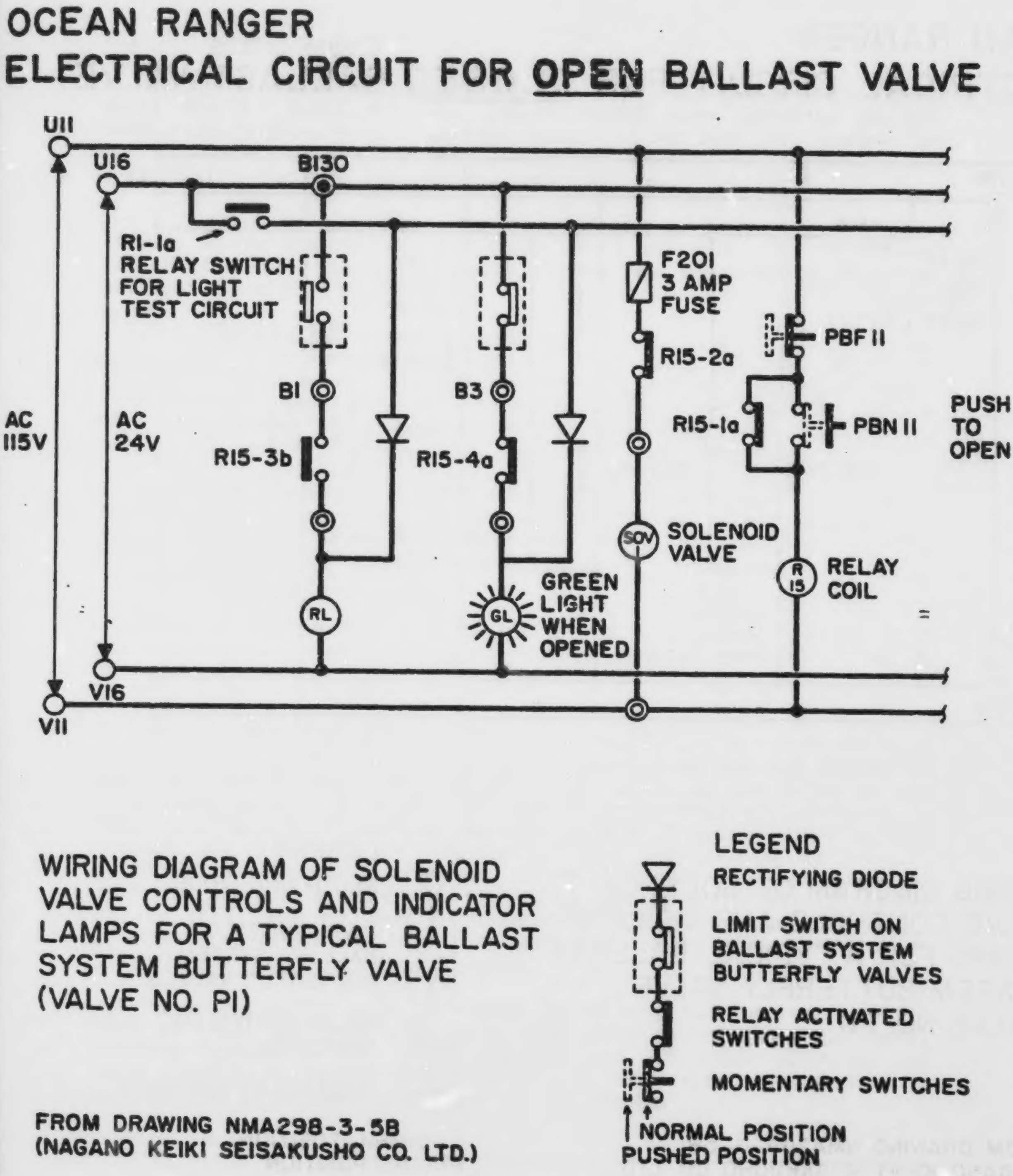
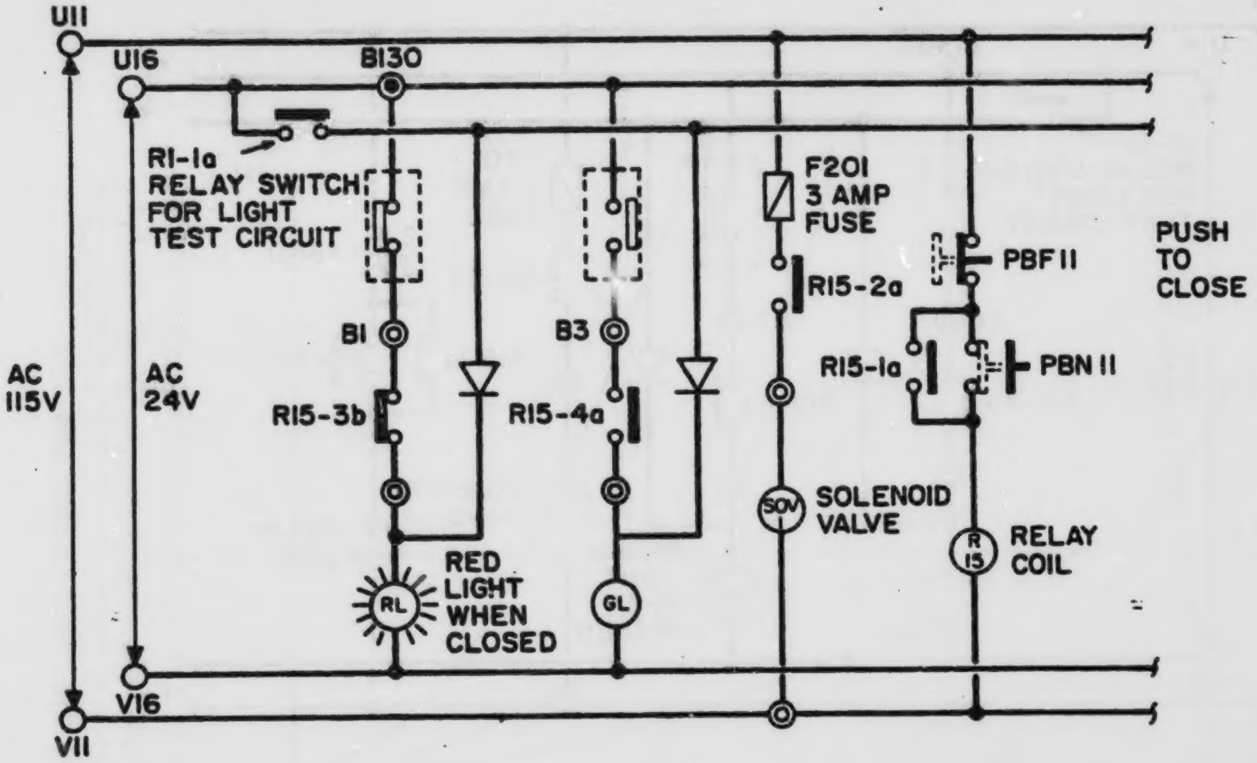

OCEAN RANGER
ELECTRICAL CIRCUIT FOR OPEN BALLAST VALVE
U11
U16
B130
R1-1a
RELAY SWITCH FOR LIGHT TEST CIRCUIT
F201
3 AMP
FUSE
PBF11
R15-2a
PUSH TO OPEN
B1
B3
R15-1a
PBN11
AC 115V
AC 24V
R15-3b
R15-4a
SOV
SOLENOID VALVE
R 15
RELAY COIL
GREEN LIGHT WHEN OPENED
RL
GL
V16
V11
WIRING DIAGRAM OF SOLENOID VALVE CONTROLS AND INDICATOR LAMPS FOR A TYPICAL BALLAST SYSTEM BUTTERFLY VALVE (VALVE NO. P1)
FROM DRAWING NMA298-3-5B (NAGANO KEIKI SEISAKUSHO CO. LTD.)
LEGEND
RECTIFYING DIODE
LIMIT SWITCH ON BALLAST SYSTEM BUTTERFLY VALVES
RELAY ACTIVATED SWITCHES
MOMENTARY SWITCHES
NORMAL POSITION
PUSHED POSITION

Figure 4.14 Electrical Circuit for Open Ballast Valve

OCEAN RANGER
ELECTRICAL CIRCUIT FOR CLOSED BALLAST VALVE


U11
U16
B130
R1-1a
RELAY SWITCH
FOR LIGHT
TEST CIRCUIT
F201
3 AMP
FUSE
PBF11
PUSH
TO
CLOSE
R15-2a
B1
B3
R15-1a
PBN11
AC
115V
AC
24V
R15-3b
R15-4a
SOV
SOLENOID
VALVE
R
15
RELAY
COIL
RED
LIGHT
WHEN
CLOSED
RL
GL
V16
V11

WIRING DIAGRAM OF SOLENOID VALVE CONTROLS AND INDICATOR LAMPS FOR A TYPICAL BALLAST SYSTEM BUTTERFLY VALVE (VALVE NO. P1)

FROM DRAWING NMA298-3-5B
(NAGANO KEIKI SEISAKUSHO CO. LTD.)

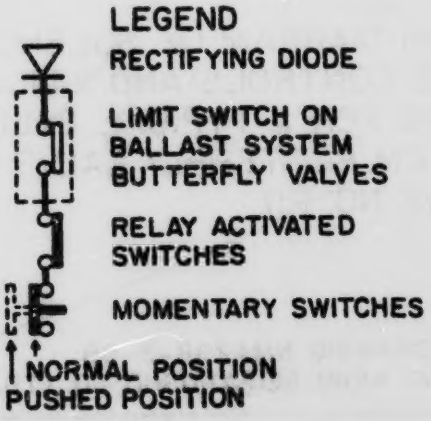

LEGEND
RECTIFYING DIODE
LIMIT SWITCH ON
BALLAST SYSTEM
BUTTERFLY VALVES
RELAY ACTIVATED
SWITCHES
MOMENTARY SWITCHES
NORMAL POSITION
PUSHED POSITION

Figure 4.15 Electrical Circuit for Closed Ballast Valve

CHAPTER 5 SEQUENCE OF EVENTS, FEBRUARY 14-15, 1982

5.1 General Summary*

In mid-afternoon of Sunday, February 14, 1982, the drilling units OCEAN RANGER, SEDCO 706, and ZAPATA UGLAND were operating on the north-eastern Grand Banks. Weather conditions had been fair during the morning, but by afternoon winds and seas had begun to build rapidly, and a major storm had been forecast for later that day.

The ZAPATA UGLAND, by afternoon, was attempting to hang off in order to wait on the weather, but was stuck in a tight hole. The UGLAND was finally forced to shear its drill string, and disconnected from its wellhead around 1630 hours.**

The SEDCO 706 was planning to engage in a fishing operation at the time. Due to the increasing severity of the weather, it was decided to postpone fishing and to wait for conditions to improve. At approximately 1855, a large wave broke over its deck, causing some damage. The 706 then disconnected from its wellhead and deballasted from its drilling draft of 80 feet to 75 feet.

The OCEAN RANGER was drilling for most of the afternoon. At 1630 it began hang off procedures, but experienced problems with high winds (70 knots) blowing its hydraulic compensator hoses into the derrick. The RANGER was finally forced to shear its drill string and disconnected between 1845 and 1900.

Winds at the RANGER site at this time were recorded at 72 knots, from the south-west. Significant wave heights were recorded as being 30 feet. Air temperatures dropped from +2.5°C at 1430 on the 14th. to -4.5° at 2330.

Between 1845 and 1930, personnel on the SEDCO 706 overheard what appeared to be an internal walkie-talkie transmission from the RANGER, in which an unidentified person reported "we had water and glass on the floor down there." At about 1950 another tranmission was overheard in which a voice (tentatively identified as Nick Dyke; junior RANGER ballast control room operator) was "mopping up water and cleaning up glass." Subsequent transmissions overheard between 1950 and 2100 concerned gas detection and public address systems being knocked out; "all the valves on the port side are open by themselves"; and a request for an ET (Electronics Technician) in the control room, along with a mention of possible electric shocks from the panel.

The broken porthole in the RANGER control room was reported to Mobil base at 2040, and mentioned in a 2106 conversation among the Mobil drilling foremen on the RANGER, UGLAND, and 706 (Jack Jacobson, Ken Lovell, and Keith Senkoe respectively). In both these transmissions it was reported by Jacobson that there was "no problem".

---

* Also see Table 5.1

** All times are Newfoundland Standard Time, based on a 24-hour clock.

One final internal RANGER transmission was overheard by the SEDCO 706, in which Nick Dyke (presumably) reported "everything OK ...... all cleaned up." The time of this transmission was estimated at 2130-2145.

No further out-of-the-ordinary events were reported or overheard from the OCEAN RANGER between 2145 February 14 and 0100 February 15. Jacobson reported everything was okay with the three rigs at 2215, and no problems were mentioned in the routine weather report from the RANGER, received by Mobil base in St. John's at 2330.

At 0100 February 15 Jack Jacobson reported to Merv Graham (Mobil Grand Banks Drilling Superintendent, St. John's) that the RANGER had an 8°-10° list to the bow. Attempts to isolate the problem had so far been unsuccessful. Graham was requested to alert the Coast Guard, and did so at 0105.

The RANGER contacted its standby vessel, the SEAFORTH HIGHLANDER, at 0105, and asked it to move closer, because the RANGER "was listing to port and all countermeasures [were] ineffective". The HIGHLANDER acknowledged and began moving closer.

At 0109 the RANGER sent out a distress call on MARISAT, giving its position and reporting a port list of 12° and progressing.

At 0110 the RANGER sent out an all stations Mayday, saying that they had a severe list. Simultaneously Jack Jacobson called Mobil base and said he would want to evacuate. He was then patched into Search and Rescue, and repeated his message, requesting Chinook helicopters. At the same time Graham alerted Mobil's helicopters at St. John's airport.

At 0115 Jacobson contacted Senkoe on the 706. He reported that the RANGER had a 12° list, and that he had alerted Mobil base and Coast Guard, asking for helicopters. He requested that the BOLTENTOR and NORDETOR (standby vessels for the 706 and UGLAND respectively) be dispatched to his aid. They were dispatched at 0121 and 0122 respectively.

At 0130 the OCEAN RANGER reported that they were going to lifeboat stations. The 706 then attempted to contact the RANGER without success.

Winds at the SEDCO 706 at 0200 NST were approximately 60 knots, from the west-south-west. Significant wave heights were approximately 30 feet, with maximum heights being observed as 50 feet and greater.

The SEAFORTH HIGHLANDER sighted the lights of the RANGER at 0207. The crew could not determine if the rig was listing, due to the motion of their own vessel. The HIGHLANDER spotted many lights in the water, then a flare, about 1800 feet downwind of the RANGER, and went to assist. At 0217 they spotted a lifeboat which was holed at the bow. The crew were bailing. The lifeboat came alongside the HIGHLANDER and a heaving line was made fast, but after several men in the boat had climbed out onto its gunwale, the boat capsized, throwing the men into the water. They were quickly immobilized by the -0.7°C water, and were lost despite the best efforts of the HIGHLANDER's crew. Elapsed time for this event was about 35 minutes. Heavy freezing spray conditions, along with high winds and waves, made operations very difficult at this time.

Between 0230 and 0240 the NORDERTOR, about 13 miles from the RANGER, picked up the rig on radar as a "normal target." The BOLTENTOR and HIGHLANDER were also visible on the screen.

Between 0235 and 0245 the BOLTENTOR arrived at the RANGER location, and approached to within one cable (600 feet) of the starboard quarter of the rig. The only lights visible by this time were one small white light forward near the waterline and one large greenish light on the aft end of the main deck starboard of midships. There was no sign of life on board the RANGER. Jim Davidson (Captain of BOLTENTOR) reported that, although the aft columns of the rig seemed somewhat high out of the water, the rig appeared level enough for helicopter landings. A crewmember out on deck, however, observed when viewing the rig from a different angle that the OCEAN RANGER had such a forward trim that its helideck was almost touching the water. After approximately 10 minutes the BOLTENTOR left the RANGER location to assist the HIGHLANDER in rescue operations.

The OCEAN RANGER disappeared from the radar of the NORDERTOR between 0300 and 0301. According to Captain Baxter Allingham, who observed its disappeararnce, the RANGER disappeared, reappeared briefly as two small "blips", then vanished for good. The elapsed time for this was about one minute. The BOLTENTOR and HIGHLANDER were still on the screen, and the BOLTENTOR confirmed about 25 minutes later that the RANGER had disappeared from its radar as well.

Wind speeds at the 706 were recorded at 56 knots gusting to 65 knots at 0300. Significant wave heights were 34 feet, with maxima of 59 feet.

Search and rescue operations continued throughout February 15. Mobil helicopters left St. John's at 0322 and 0345, arriving at the scene of the accident at approximately 0445 and 0455. Search and Rescue aircraft began arriving at the scene at approximately 0900. No survivors were discovered after the loss of the men near the HIGHLANDER, although many lifejacketed bodies were sighted, most clad in work vests and/or coveralls (although one clad in a helicopter survival suit was recovered). Attempts to recover the bodies met with only limited success.

5.2 Summary of Environmental Conditions: February 13-15, 1982

Sustained wind speeds recorded at the OCEAN RANGER rose from 34 knots at 2330 Feb. 12 to 40 knots 0230 Feb. 13. Wind direction veered from 270° true to 300° over the same time interval. Winds gradually decreased to 4 knots (from 290°) by 2030 on Feb. 13 (See Table 5.2).

By 0230 Feb. 14 winds had backed around to 130°, and increased in speed to 29 knots. Between 0230 and 1130, they remained variable in direction (between 100° and 130°), but increased in speed to 47 knots.

By 1430, the wind speed had increased to 67 knots, and its direction had changed to 210°. Speeds continued to increase over the next six hours, with 72 knot winds from 220° being recorded at 1730 (gusts of over 80 knots were observed between 1530 and 1630). Winds decreased somewhat to 58 knots by 2330, veering to 270°, and gradually decreased to 38 knots by 2330 on Feb. 15.**

Significant wind wave heights increased from 8 ft. at 2330 Feb. 12 to 16 ft. at 0830 Feb. 13. The wave period increased from 7 to 9 seconds. Wind wave conditions became light by 2330 Feb. 13, remaining so until 0530 Feb. 14; however, swell waves of height 7-8 ft. from a direction of approximately 290° with periods of 12 seconds were noted during this time interval.

Significant wind wave heights increased to 15 ft. by 1130 on Feb. 14, with a wave period of 8 seconds, then increased rapidly to 31 ft. by 1730. Sea heights continued at 33 ft., with a period of 12 seconds, until 2330, and remained at approximately 30 ft. until 0830 on Feb. 15. Wave heights and periods then slowly decreased, with 20 ft., 10-second waves being recorded by 2330.

Maximum observed waves were recorded at 50 ft. or more from 2000 Feb. 14 to 0400 Feb. 15. Maxima of 61 ft. were observed at 1830, 2230 and 2330 on the 14th., and at 0330 on the 15th.

Air temperatures at the RANGER fell from -2.5° at 2330 Feb. 13 to -6.4° at 1730. Temperatures gradually increased to -3.5° at 0530 Feb. 14, then rose more rapidly, reaching a high of +2.5° at 1430. They fell to -4.5° at 2330, then dropped further, to -6.2°, at 0830 Feb. 15. Temperatures remained between -5°C and -7°C for the remainder of the day.

Sea surface temperatures were roughly constant about -0.7°C between 2330 Feb. 13 and 1130 Feb. 14. They dropped to -1.6° by 2030, rose to 0.0°C at 0230, then fell to -1.7°C at 0530. Following this, the sea temperature rose, reaching +0.5°C at 1130, and remaining roughly constant at that value until 2030. By 2330, it had fallen to a low of -0.7°C, and remained at -0.5°C until 0530 on Feb. 15. The sea surface temperature then began dropping steadily, reaching -2.0°C at 2330 Feb. 15.

The barometric pressure at the OCEAN RANGER rose from 1009 millibars (mb) at 2330 Feb. 12 to 1029 mb at 1730 Feb. 13. It decreased gradually to 1027 mb by 2330, then dropped rapidly to 974 mb at 1730 on Feb. 14. The pressure remained steady for roughly three hours, and rose to 996 mb by 0830 on Feb. 15. Barometric pressure increased gradually for the rest of the day, reaching 1009 mb by 2330.

Visibility was fair to good in the morning of Feb. 13, ranging from 2 to 11 nautical miles, with a low of one to two nautical miles (n.mi.) at 0230. Visibility was uniformly excellent from 1130 Feb. 13 to 0230 Feb. 14, at 11-27 n.mi., but deteriorated rapidly afterwards, becoming 0.03-0.1 n.mi. at 0530, and remaining below 1 nautical mile for the rest of the day, except for a brief improvement to 2-5 n.mi. at 1130. Visibility steadily improved on Feb. 15, becoming 1-2 n.mi. between 0230 and 0530, 2-5 n.mi. from 0830 to 2030, and 11-27 n.mi. at 0230.

** The last synoptic weather report from the OCEAN RANGER was submitted at 2330 Feb. 14. Environmental data from the ZAPATA UGLAND was used from that time onwards.

5.3 Detailed Chronology

5.3.1 OCEAN RANGER

Early February 14th, 1982, the OCEAN RANGER was drilling the Hibernia J-34 well (location: 46°43'33"N, 48°50'13"W). The morning forecast from NORDCO Limited for the drillsite was as follows:

Warning in effect Storm, wave and freezing spray.

Valid Time	14/12Z	14/18Z	15/00Z	15/06Z	15/12Z	15/18Z	16/00Z
NST	0830	1430	2030	0230	0830	1430	2030
Wind							
Direction	140	160	300	280	270	310	300
Speed	50	65	45	40	35	30	25
Max Speed	60	90	55	50	45	40	35
Sea Wave							
Sig Height	14	22	14	16	18	20	14
Max Height	24	37	24	27	31	34	24
Period	8	10	8	9	9	10	8
Swell Wave							
Direction	Nil	140	180	360	300	Nil	010
Height		10	16	10	10		10
Sky	OBSCD/OVC..		OVC	OVC OCNL OBSCD		OVC/BKN....	
Air Temp.	-1	+6	0	-3	-4	-5	-6
VSBY	1-2 OCNL 1/3		1-5	1-5 OCNL 1/2		6+ OCNL 4	

Outlook valid 00Z Monday to 24Z Wednesday.

Monday wind NW 30 BCMG SE 20 VSBY good MCS 25 ft.
Tuesday wind SW 20-30 VSBY good MCS 15 ft.
Wednesday wind SW-NW 20-30 VSBY good MCS 15 ft.

Synopsis:

A 950mb storm center was located at 44.5H 58.8W at 14/0900Z. It moving northeast at 40 knots, forecast positions are 46N 57W and 49.5N 53W at 14/1200Z and 14/1800Z respectively. Note the forecast trajectory of the low center has been ammended to more northerly than the previous forecast, but drastic deepening of the pressure center will create higher winds and waves earlier than expected in the previous forecast. Cold front associated with this storm is forecast to pass over the rigs shortly after 14/1800Z.

Wind speed in knots, wave heights in feet, periods in seconds, all directions in degrees true, visibility in nautical miles, temperatures in celsius."

At 1430 February 14, winds at the OCEAN RANGER site were recorded at 67 knots from a bearing of 210°; significant wave heights were recorded at 15 ft., with a period of 9 seconds. A swell wave of height 10 ft., bearing 130°, and period 9 seconds was also observed. Air and sea surface temperatures were recorded at +2.5°C and +0.5°C respectively.

Peter Kapral (Senior Drilling Foreman, Mobil base) testified in a deposition to the USCG that at 1630, Bob Madden (Mobil Drilling Foreman, OCEAN RANGER) informed him that

> "at the time he was drilling and would proceed to pull out to hang off."**

Also at 1630, the RANGER sent Mobil base the aviation weather report.

Kapral testified that at 1642 Madden called him and reported that

> "he was hanging off at the time and called to inform me that he was having a few problems with the winds... the wind was gusting to 70 knots and blowing the compensator hoses out the side of the derrick."

At 1700 the RANGER submitted synoptic weather information to Mobil base.

At 1730, winds at the RANGER site were recorded at 72 knots, bearing 220°. Significant wave heights were 31 ft., with a period of 9 seconds. Air and sea surface temperatures were -1.0°C and +0.6°C respectively.

Merv Graham (Grand Banks Drilling Superintendent, Mobil base) testified to the USCG that,

> "At 1845 hours, "Received call from OCEAN RANGER, Jack Jacobson [Mobil Drilling Foreman]. He advised me they had hung off in the middle rams, the bit was in the casing, sheared the drill pipe with the shear rams. The riser was disconnected and they were riding out the storm. He also advised me that the tensioning ring had hung up once on the spider deck area and at the time of disconnect they were getting 20-foot heaves, with spray up into the spider deck area to the rig floor. Jack advised me the rig lost time with the compensator hoses hanging up in the derrick resulting in not hanging off normally and forced to shear the drill pipes. Jack also advised the storm had built extremely fast during the half hour before disconnecting."

A MARISAT call from Kent Thompson (Toolpusher, OCEAN RANGER) to Jimmy Counts (ODECO Drilling Superintendent) was logged at 1858. Counts testified that

> "He just informed me that he had suspended operation at, that they had hung off the drill pipe and sheared the drill pipe and unlashed the rod and they were waiting on the weather."

** Unless otherwise noted, all quoted testimony is from the hearings of the U.S. Coast Guard Marine Board of Investigation in April and July of 1982.

Fred Hatcher (Watch Stander, SEDCO 706) testified to the USCG that he overheard a radio voice transmission from the OCEAN RANGER

> "somewhere quarter of seven, 730, somewhere in that area" (i.e. 1845-1930), reporting
>
> "we had water and glass on the floor down there."

It is assumed that a porthole was broken out of the RANGER's ballast control room immediately before this transmission.

At 1908 a call was logged between the OCEAN RANGER and SEDCO 706. Keith Senkoe (Mobil Drilling Foreman, SEDCO 706) testified to the USCG that

> "He [Jacobson] just called and said that he was attempting to hang off. I suppose he was checking on our status as well, what we were doing at the time and he called and said that he was attempting to hang off but he had got his compensator hoses fouled in the derrick and he was having a problem getting that sorted out and at the same time he mentioned that a window had been knocked out of the control room and there was some water and glass and such."

At 1930 the weather observer on the RANGER called Mobil base to submit weather information one hour early, by mistake.

At 1940 the RANGER received NORDCO's weather forecast from Mobil base:

"Forecast for the SEDCO 706, ZAPATA UGLAND and the RANGER issued by Nordco Limited for Mobil Oil Canada at 1930 NST Sunday, February 14, 1982 valid until 0830 NST Tuesday with an outlook for the next three days.

Warnings in effect Storm, wave and freezing spray continued.

Valid Times	15/00Z	15/06Z	15/12Z	15/18Z	16/00Z	16/06Z	16/12Z
LCL Times	2030	0230	0830	1430	2030	0230	0830
Wind at Anemometer							
Direction	270	330	330	330	310	260	200
Speed	75	70	60	50	40	25	35
Maxspeed	90	80	75	60	50	35	45
Sea Wave							
Sig Height	25	33	30	20	15	6	10
Max Height	44	59	54	35	25	10	17
Period	9	10	10	9	8	6	7
Swell Wave							
Direction	320	Nil	Nil	Nil	Nil	330	310
Height	15					16	16
Period	9					9	8
Sky	OBSCD......		OVC	OVC	BKN	SCT	BKN/ OVC
Air Temp	-2	-5	-9	-6	-3	+1	+5
VSBY	2-4 VRBL 1/8-1		6 OCNL 2-4		6	6	2-4
Weather	SW-/SW......		OCNL SW-....		Nil	Nil	MIST/ R-
Freezing Spray	Moderate to heavy......		Light to Moderate			Nil	Nil

Outlook valid 12Z Tuesday to 24Z Thursday.

Tue.	Wind SE 30-40	VSBY poor	MCS 16 ft.
Wed.	Wind NW 30-40	VSBY fair	MCS 20 ft.
Thu.	Wind NE 20-30	VSBY poor	MCS 13 ft.

Synopsis:

A cold front from a storm center, east of the Avalon Peninsula about 2000Z, extending southward along 50 W will lie over the rigs between 0100-0300Z. Storm force northwesterlies, poor visibilities and rough seas will persist tonight.

A ridge of high pressure over Quebec will move to the drilling area Monday night, maintaining strong southwesterlies, good visibilities and seas 10-15 feet mostly from northwesterly swells.

A warm trough from a deepening low moving to southern Labrador will extend along western Newfoundland. This system will bring southwesterly gales and by Tuesday morning, fair to poor visibilities in fog and rain. Rainshowers and increasing temperatures are expected on Tuesday.

Wind speed in knots, wave heights in feet, periods in seconds, all directions in degrees true, visibility in nautical miles, temperatures in celsius."

Testimony of Donald King (Barge Engineer, SEDCO 706) to the USCG concerning events between 1950 and 2100:

> "After I come back in we had our four thrusters running then. I checked those, checked our anchor tensions. We were riding the storm fairly well. At that point we started hearing conversations on our VHF Channel 6. We could overhear somebody on the OCEAN RANGER talking ... We overheard conversations that they were mopping up water and cleaning up broken glass. In this timeframe from ten to eight until nine, a little after nine, we picked up two or three different conversations. One being the broken glass and water, another being that their P.A. system was knocked out. Their gas detection system was knocked out, everything appeared to be okay. They were cleaning, they said everything looked okay. "We are still cleaning up water." Sometime after 9 o'clock we heard they were getting shocks off different panels and they wanted the E.T. man, electronic technician to come down to the control room and at some point along there they said valve or valves were opening and closing on their own ...
>
> This was a voice on a portable VHF radio and I, myself, and the watch on duty we recognized the voice as being Nick Dyke. [Ballast Control Room Operator, OCEAN RANGER]"

Testimony of Fred Hatcher concerning events in the same time period:

> "Yes, I heard an ashore after that all the valves on the port side are open by themselves ... in the minute or two passed and next thing I heard was received the okay and the next thing after that he said he needed an electrician down here because of the water, shock because of the water in the ballast ...
>
> We heard the statement and they would be all you hear, just, you know, one statement. That was it. And it wasn't continuous talking, just one statement, stop and then the other statement."

Testimony of Jim Davidson (Captain of the BOLTENTOR, standby vessel for the SEDCO 706):

> "At about the mid watch. I cannot place it any closer than that, we heard some conversations on what I took to be hand-held VHF sets, walkie-talkies, to the effect that or initially establishing contact. Can you hear me; Yes, I can hear you now, whatever. And then a voice said, well, there is broken glass in here and there is water in here and another voice said, I will get it cleaned up, get some guys in there and get it cleaned up. Then another voice yet, a third voice, said, well, there is some high-powered cables down there. And the second voice came back and said, Well, don't have anybody injured or killed, but obviously still get the water cleaned up. And the last thing I heard was another voice saying, Well, there is some valves operating or opening or closing. I can't remember the exact words, but it was to do with valves operating."

Regarding the time of these events, Davidson further testified as follows:

> "It was over about a period of ten minutes, approximately. Just sort of an instant in the middle of the watch and both James Eby [Chief Engineer, BOLTENTOR] and myself heard it. Of course, we discussed it afterwards and at this time we didn't even realize that it was the OCEAN RANGER. In my mind I was on standby for the 706 and I thought that it was actually the 706."

At 2030 the RANGER sent Mobil base the synoptic weather report. Winds at the RANGER site were recorded at 72 knots from 240°. Significant wave heights were 33 ft., with a period of 12 seconds. Air and sea surface temperatures were -2.2°C and +0.6°C respectively.

Merv Graham testified that:

> "At 2045 hours, [logged at 2040] "Received call from OCEAN RANGER, Jack Jacobson. I do not know if I initiated the call or not. It was on the MARISAT. Jack advised me they had 50 foot plus maximum combined seas and winds in the 90/100 knot range. He advised me that one wave had taken a window out of the barge control room. He advised me there was no problem with this window outing and from memory he advised me that all that was required was to mop up a little bit of water in the room and that all of the equipment was functioning properly at that time. He advised me that the anchor tensions were all in the 240,000 range. Also that the barometer had leveled off, everything was normal at the rig. They had no problems. The remainder of our discussions at that time centred around the equipment he would require to mill off the top of the sheared drill pipe and the overshot and tools necessary to recover his drilling string in view of a plane waiting to bring extra fishing equipment from Drillrite in Edmonton, Alberta. I requested Jack Jacobson at this time to talk to the foreman at the 706 and the UGLAND and discuss with them their anchor tension and how they were riding out the storm and call me back."

A radio conversation between Keith Senkoe, Ken Lovell (Mobil Drilling Foreman, ZAPATA UGLAND) and Jack Jacobson was logged at 2106. Senkoe testified to the USCG that:

> "He [Jacobson] just finished talking with Merv Graham and Merv asked him to contact the other two rigs to see how everybody was doing, so he did. He talked to the UGLAND first, I am pretty sure, and then me second. During that conversation he just commented that he had sheared and disconnected and basically that was it, but a few comments about the weather."

Ken Lovell's testimony concerning this conversation:

> "To the best of my recall Keith and I struck up the conversation initially. We just identified the status of each of our respective rigs. Jack came in and we asked him what his status was. And he said to the best of my recall, he said, Don't worry about it, Ken, we had to snip our pipe off, too, or something to that effect. And both

> Keith and myself wondered why he had, in fact sheared his drill pipe and felt that he should have been able to get his hang off tool in the hole and hang off, back off that tool bit without shearing the drill pipe.
>
> Both Keith and I felt that he would have been in the best position to get hung off in a normal conventional manner and back off the drill pipe and avoid shearing off and so we pursued that with him and he suggested that they had a problem with the compensator and they lost their ocean compensator function and were forced to shear ... The discussion was, you know, he had lost the function of the compensator and he had suggested that the hydraulic lines had been carried outside the derrick and wrapped up and broke some hydraulic lines. And, in fact, caused a loss of the function of the compensator ...
>
> ... And there was the porthole we discussed previously and put aside as being no problem. The water had been mopped up and that took place, the conversation at 10:15. [Lovell's estimate of the time of this conversation was 2215; however, it was logged by the 706 radio operator at 2106].
>
> They just said that they had knocked the window out and they were taking on some water, but they mopped it up and there was no problem."

Rod Fraser (Mobil Drilling Foreman, SEDCO 706) overheard this conversation, and testified that, in addition,

> "I think that he also said that he had come up and I think it was in the same conversation with Ken Lovell on the ZAPATA UGLAND. I am pretty sure that Ken Lovell said that they had pumped up to survival draft and I think Jack Jacobson said that he hadn't pumped up to survival draft. One of those conversations he said that and just thinking back last night I think it had to be in the second one that he said that ...

Donald King and Fred Hatcher both testified that "around 9:30... quarter of ten", they overheard one last transmission from the RANGER. King testified that the personnel on the RANGER were:

> "Just indicating that they were, the water had been cleaned up and everything had looked okay. They had gotten the E.T. man, electronic technician, down to their control room and they were talking from their control room to probably one of their offices and passing on that everything looked okay."

Hatcher testified that:

> "I heard a voice that I took to be Nick Dyke saying everything seemed to be okay down here and I am going to get her all cleaned up and everything seemed to be okay... I recognized Nick Dyke at that time."

Ronald Duncan, Captain of the SEAFORTH HIGHLANDER (standby vessel for the OCEAN RANGER) testified that:

> "At sometime during the 8 to 12 watch on the evening of the 14th -- I would estimate that time to be 2200 hours local time, all times being local -- the OCEAN RANGER called the SEAFORTH HIGHLANDER on Channel 6 VHF and asked if the SEAFORTH HIGHLANDER was weathering the storm satisfactorily. I replied in the affirmative. I said, "Yes, we are okay, not too comfortable, but we are all right," and he said, "That is fine. I'll check back later," and I said, "Okay. Thank you very much for calling", and that was the end of that radio transmission."
>
> ... The rig did not check back to see if we were okay after that, and that was the last communication I had with the OCEAN RANGER until 0105 hours on the 15th of February."

Donald King and Fred Hatcher on the 706 overheard the preceding conversation, but could not narrow down the time of its occurrence any more than Duncan. King estimated it as "close to 11 o'clock", and Hatcher's best recollection was "somewhere around 9 o'clock."

A call from Jack Jacobson on the RANGER to Merv Graham at Mobil base was logged at 2215. Graham testified that, "at 2200 hours",

> "... I received a call from the OCEAN RANGER, Jack Jacobson, as requested previously to inform me of the status of the other two semi-submersibles. On the OCEAN RANGER, Jack advised me the maximum combined seas were in the 55 foot, the odd wave going up in the 65-foot range. I asked Jack if he was having any problems in the barge control room with the window being taken out, and he assured me that all of the equipment was functioning normally. On the UGLAND he advised me they had lost one guide line, that the winds were in the 80-85 knot range, maximum combined seas in the 35-55 knot range, maximum combined seas in the 35-55 foot and some higher. The SEDCO 706 had disconnected and they had the thrusters on 75 percent power. I do not have it noted nor can I remember which call, but I was aware, which is normal procedure, that once the rigs have disconnected the riser they will deballast the rig up five to ten feet to gain more air gap and also to lessen the chance of seas breaking on the main-deck level. I ended my conversation with Jack Jacobson with us both in agreement at that time that the rigs were all riding out the storm with no problems, and Jack indicated that the wind and the seas had come down slightly from what they had been previously. All that we could do was ride the storm out for the night and I would talk to them in the morning."

At 2330 the RANGER sent Mobil base the synoptic weather report. Winds at the RANGER site were recorded at 58 knots, from 270°. Significant wave heights were recorded at 33 ft., with a period of 11 seconds. A swell wave of height 23 ft., direction 230°, and period 9 seconds was also recorded. Air and sea surface temperatures were -4.5°C and -0.7°C respectively.

At 0100 on February 15, Merv Graham received a call from Jack Jacobson via MARISAT. Graham testified to the USCG that:

> "I was talking to Jack Jacobson at the OCEAN RANGER. If he wants, I can read through the notes. "0100 hours, one or two minutes either side as I had just glanced at my watch, I received a call from the OCEAN RANGER, Jack Jacobson. He was calling to request me to alert the Coast Guard. The OCEAN RANGER was listing to the bow eight to ten feet which I am sure is degrees. I did not question Jack on it. They had 75 to 80 mile an hour winds. They did not know what the problem was. The stand-by boat was the HIGHLANDER. I did request from Jack how many people were on board, and he advised me of 84 men on board. Jack Jacobson at this time was cool, calm and collected. I recognized from the tone of his voce and from the information he had given me that they had a serious problem. I advised him that I would have work boats on the way to him and that our helicopters would be activated and that I would proceed to the office and that is where he would be able to get in contact with me next."

When asked further if it seemed that Jacobson knew what was causing the list, Graham testified:

> "No, he didn't. He didn't seem to have, he seemed to be fighting a problem he didn't understand."

Ronald Duncan of the SEAFORTH HIGHLANDER testified to the USCG that:

> "At that last time, 0105 hours on the 15th of February, the OCEAN RANGER called up the SEAFORTH HIGHLANDER again on Channel 6 VHF and asked the HIGHLANDER if she would come in a little closer. I'll try to remember his exact words for you. He said, "SEAFORTH HIGHLANDER, will you come in a little closer, please" He said, "We've got a problem here on the rig," and I said, "Yes, certainly I'll start coming in closer now." I said, "Would you like to discuss this problem with me" He said, "Stand by," and approximately half a minute later he came back on the radio and he said, "Yes. We have a list," or, "We are listing to port and all countermeasures are ineffective, so if you could come in close as soon as you can make it," and I said, "Right. I'm on my way. We are coming in now," and that was the end of my communication with the OCEAN RANGER and in fact that was the last communication I ever had with the OCEAN RANGER."

When questioned further on the precise wording of the RANGER's message, Duncan reiterated that:

> "I have a pretty accurate recollection. He said either, "We are listing to port," or, "We have a list to port and all countermeasures are ineffective ... He actually said, "All countermeasures are ineffective."

At 0109 the OCEAN RANGER sent out a distress call on MARISAT. The following (USCG exhibit 28) is a verbatim transcript of the transmissions (parentheses added for clarification):

" (2/15/82)

HOT 0439Z

CENB 1330702

ARE EXPERIENCING A SEVERE LIST U NABLE TO CORRECT PROBLEM.
NOTIFYING YOU PF PROBLEM PLEASE QSL

(TELEX SWITCH OPTR-COMSAT) DO YOU WISH CONNECTION TO COAST GUARD
AND WHAT SATELLITE ARE YOU ON GA

(O.C.) R R I WUD WISH CONN AM ON SATELLITE

(TELEX SWITCH) DO U WISH COAST GUARD NYK OR SAN FRANCISCO GA

(O.C.) NYK PLS

(TELEX SWITCH) MOM
230127775+ CONNECTION MADE WITH USCO RCC NYK 0422.62 15 FEBRUARY

USCO RCC NYK
USCO RCC NYK

CENB 1330702

(O.C.) WE ARE THE ODECO OCEAN RANGER KRTB LOC 46.43.33 N
48.50.13W AND ARE EXPERIENCING A SEVERE LIST OF ABOUT 10-15
DEGREES AND ARE IN THE MIDDLE OF SEVERE STORM AT THE TIME
12 DEGREES AND PREGRESSING..REQUEST ASST ASAP..WE ARE AN
OFFSHORE DRILLING PLATFORM..

(O.C.) DE RCC NYK WILL PASS INFO
(O.C.) RR WE WILL STBY AS LONG AS POSS
CENB 1330702
(O.C.) WINDS AT THIS TIME ARE APPROX FROM THE WEST AT APPROX
75 KNOTS
RIG IS OF SEMI-SU SUBMERSIBLE BUILD AND IS LISTING SEVERELY
12-15 DEGREES TO THE PORT SIDE..GENL INFO
CENB 1330702

(O.C.) USCO RCC NYK
INFO HREEE
INFO IS BEING FORWARDED TO RCHALEE RCC HALIFAX
OR
(O.C.) R RGA
(O.C.) R R WE CHECK THAT ALL AVAILABLE WORKBOATS IN THE
IMMEDIATE AREA ARE COMING TO OUR ASST THERE ARE TWO OTHER
SEMI SUBMERSIBLES IN THE AREA AND WILL DO ALL POSSIBLE
TO ASSIST

OR
(C.O.) R R WILL ALSO PASS THIS INFO "

Richard Flynn (Radio Operator, Mobil base) testified to the USCG that:

> "At 10 after 1 the radio operator called [from the RANGER]. I forget the exact words he used, but he advised that he had a mayday, they were listing badly and were to notify Search and Rescue and the 706 picked up the message at the same time and he began to put out a mayday on 2182 and I called the Coast Guard at St. John's Search and Rescue on the telephone and advised them.
>
> The drilling foreman came on with him, almost like together, they have the radios in the radio room and they have what you would call an extension in the foreman's office. So, I am not sure if he was in his office or they were both on there in the radio room, but the foreman came on and he just repeated they had a mayday and the rig was listing badly and that they were going to want to evacuate.
>
> I had Search and Rescue on the phone between 1:10 and 1:30 and phone patched them into the OCEAN RANGER. The contact wasn't very good. I believe they could hear the OCEAN RANGER fairly well, but he couldn't hear them too good. They didn't give any details at all. They just said they were listing badly, wanted to evacuate and they wanted three or four helicopters, Chinooks to come out and take them off ...
>
> He specified Chinook. He said something like, "That is the only thing that will get out here in this kind of weather ..."

The SEAFORTH HIGHLANDER also heard this message. Captain Duncan testified that:

> "At 0110 hours I overheard on VHF Channel 6 the OCEAN RANGER calling the SEDCO 706. SEDCO 706 immediately replied, and the OCEAN RANGER advised the SEDCO 706 to send out a mayday relay regarding OCEAN RANGER immediately. SEDCO 706 questioned this by saying, "You want me to send out a mayday relay now" The OCEAN RANGER said, "Yes, send it out now, and if you try calling us back afterwards and don't get any reply from us, then you know we have already taken to the lifeboats."
>
> I believe the SEDCO 706 said something like, "Okay. I'll send it out now," and that was the end of that transmission. Immediately we overheard on 2182 kilohertz the mayday relay being broadcast by SEDCO 706 for the OCEAN RANGER. He broadcast that message immediately afterwards. He was very very quick to do it."

Keith Senkoe on the 706 testified that, at 0115:

> "Jack called me and asked or requested that I send my standby boat and also arrange to have the one from UGLAND sent over as he was about a twelve degree list forward he told me and if I could forward the boats to him ... because he was suspecting that he was going to have to abandon ship ... On this last conversation I had with Jack he had informed me that he had sent out a mayday and alerted the Coast Guard."

At 0130 the RANGER called Mobil base and informed them they were going to lifeboat stations. This was overheard by Baxter King (Radio Operator, SEDCO 706), who testified that:

> "At 0500 Zulu the OCEAN RANGER called Mobil base and advised them that they were going to liferaft stations. This was directed to Mobil base, but seeing the situation I copied" ...

Rod Fraser of the 706 also overheard this transmission, and testified that

> "That conversation was called to the the radio room and we had our remote set turned on so we could listen to what was going on. I believe that conversation called to the radio room asking them to continue relaying the mayday and they were reporting to the lifeboat stations and there were no further communications."

This was the last transmission received or overheard from the OCEAN RANGER.

5.3.2. Standby Vessels

On the afternoon of February 14, 1982, the supply vessels NORDERTOR, BOLTENTOR, and SEAFORTH HIGHLANDER were standing by the ZAPATA UGLAND, SEDCO 706, and OCEAN RANGER respectively.

Between 2100 and 2200 the OCEAN RANGER contacted the SEAFORTH HIGHLANDER to check its condition; the HIGHLANDER replied that it was weathering the storm satisfactorily*.

The captain of the BOLTENTOR testified that he overheard internal radio transmissions from the RANGER around the middle of his watch (around 2100-2200). In these transmissions Davidson said he heard various voices discussing "broken glass ... and water in here", "I will get it cleaned up", a warning about "high-powered cables down there", and a report that there were valves opening and closing.

At 0105 on February 15, according to the testimony of the SEAFORTH HIGHLANDER's captain, Ronald Duncan, the RANGER called the HIGHLANDER and requested that it come to close standby, saying that the rig had a list to port and that "all countermeasures are ineffective." The HIGHLANDER immediately began moving closer. Duncan testified that he was maintaining a holding pattern "head-on to the sea and swell" (corresponding to a heading of about 250° true), and that at the time of receipt of the RANGER's message "I was approximately 8 miles off the rig ... to the south of the rig ..."

At 0110 all three standby vessels overheard the RANGER's request to the SEDCO 706 for a mayday relay. The HIGHLANDER immediately increased its speed to full maximum speed.

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* In cases where testimony concerning an event is quoted in a previous section, a summary only is given.

At 0121** the BOLTENTOR was dispatched to the RANGER location. The captain, Jim Davidson, described his holding pattern prior to this as follows:

> "At midnight, yes, we turned downwind, [seas were approximately from 250°] and by about 1 o'clock, or just before 1 o'clock we were abeam of the 706, i.e., a mile. Possibly a mile south of her." (i.e. about 7 nautical miles north-east of the RANGER)

At 0122 the NORDERTOR was dispatched to the OCEAN RANGER's assistance. Captain Baxter Allingham, in testimony to the USCG, described his holding pattern with respect to the ZAPATA UGLAND as follows:

> "We were keeping, keeping within close to a two-mile radius. Usually we would go upwind probably three, four miles, so you can come downwind fairly fast rather than if you are downwind very far it would take quite a while to get back up again."

Allingham further testified, that, relative to the UGLAND,

> "We were probably, approximately, I would say from when I came on the bridge, about two miles to the north which left us twenty miles from the RANGER,"

when they were dispatched to the RANGER location.

At 0156 the BOLTENTOR reported to the SEDCO 706 that it was 4.6 miles from the RANGER location, and at 0157 the NORDERTOR reported it was three hours away.

At 0200 the sustained wind speed at the SEDCO 706 was 61 knots, from a direction of 260°. Significant wave heights were recorded at 30 ft., with maximum observed waves of 50 ft. Wave period was 10 seconds. Air and sea surface temperatures were -3.0°C and 0.0°C respectively.

At 0207 the HIGHLANDER reported to the 706 that it had sighted the lume of the OCEAN RANGER from a distance of about 8 cables (4800 feet).

At 0211 the HIGHLANDER reported making visual contact with the RANGER. Captain Duncan of the HIGHLANDER testified that

> "We had driving snow conditions, a lot of spray from the sea, and visibility was very very poor indeed. We came to a position approximately two cables [1200 feet] off the rig, downwind of the rig, and we could see the rig apparently illuminated as normal, fully illuminated, with the derrick illuminated, all the docks, the accommodation illuminated. We could not tell if the rig was listing because we ourselves were performing in such a way that it would be extremely difficult to judge if the rig was listing.

** Unless otherwise noted or quoted from testimony, all further times in this section are as noted in the barge control log of the SEDCO 706 (USCG Exhibit 4).

"... We arrived at the close standby position two cables downwind of the rig at 0150 hours."

(Despite the latter time estimate, the HIGHLANDER's report of the sighting was logged at 0207 by the 706).

Duncan continued:

"... And almost immediately at that time we observed small lights in the water approximately four, five points on the starboard bow, and we sighted a red distress flare approximately four points on the starboard bow at the same time."

At 0212 the BOLTENTOR reported to the SEDCO 706 that it was 3 miles from the RANGER position.

At 0214 the HIGHLANDER reported to the 706 that it was proceeding to a flare. Duncan testified that

"... I proceeded towards the red distress flare, and while proceeding to it another flare from the same source went up. Probably about three minutes after sighting the first flare we visually sighted a lifeboat ... Just before we got to the lifeboat one of these little lights appeared dead ahead of me. I was in full speed. He was very very close to me. So I put the stakes from full ahead to full astern and put the bow thrust hard over to the port and maneuvered clear of that little light and then brought my vessel into this position here close to the lifeboat (indicating). The little light was very close to the lifeboat, that particular little light ... I maneuvered my ship very close downwind of the lifeboat. The lifeboat was under power because he steamed across a swell, across my stern from starboard side to port side, and he maneuvered his lifeboat down the port side of my vessel on the port quarter ... At no time did the SEAFORTH HIGHLANDER strike or run down any lifeboat, which has been indicated in some press reports from thoughtless comments made by other people, that whoever was steering this lifeboat knew what he was doing and he handled a boat before, because it was quite a feat of seamanship bringing that across the swell and maneuvering down to my port side in these conditions. He did a good job of it. He made a good approach. The SEAFORTH HIGHLANDER never struck the lifeboat at all ... I maneuvered my ship very close to him, slightly downwind of him, and then he came in the rest of the way to me, yes ... The condition of the lifeboat appeared to be in good shape. It was high in the water ...

When he came alongside, the man on deck saw a hole in the bow, and the mate told me it was on the waterline either side of the stern ... but the top deck of the lifeboat was okay ...

... At some time when we were -- I think it was when we had the lifeboat alongside us before it capsized the SEDCO 706 called us up [logged at 0232] and he said, "What's happening; What is the position What's going on now ". And I said, "I've got a lifeboat alongside me. There are men in it. There are survivors in it. I am trying to get them off. In my opinion there has been a major disaster here," and he said, "Okay," and I think he appreciated my position and he didn't bother me with any further communications ...

... I understand there were two life rings with lines attached thrown to the boat. One line was made fast. I understand there were two heaving lines also thrown, but I only know of the one actually being made fast with the lifeboat ...

The size of that line of the life ring -- it is small, three-quarter inch diameter, polypropylene, probably about 120 feet long ...

... One line was made fast on the lifeboat, and the other ring was made fast to my ship. Then some men began to come out of the enclosed boat, and they stood on the port side of the lifeboat, which was the side away from my vessel -- four or five, maybe six men came out and stood on the port side.

... Sometimes the lifeboat was just touching the SEAFORTH HIGHLANDER but not especially violently. At other times she was about six feet off the SEAFORTH HIGHLANDER. She was moving in and out a little. It was at that time that the lifeboat began to capsize to port in a very slow manner, like watching a slow motion picture. The men standing on top of the boat were thrown into the sea. The boat remained capsized. I believe during the capsize of the lifeboat the line we had made fast to it parted. After it had capsized it was approximiately 12 feet maybe off the SEAFORTH HIGHLANDER, and I could see what I estimate to be eight or nine men clinging to the boat in the water. I could see all these men. They had life jackets on, and there was a light on each life jacket.

... At about this time I was taking heavy seas in the after deck of my vessel which was sterned to wind and sea. The mate and one of the seamen were washed up the deck, but they were both okay, although they suffered some bruising. The gangway net was washed over the side. We were still along the lifeboat, and after maybe a minute and a half or two minutes -- it is very difficult to estimate -- the men clinging to the boat began to let go, and they drifted down my port side. At that point I shouted down to the mate on the deck via the loud hailer system to throw over a liferaft. I saw the men running up forward on my deck to go for the liferaft, and they threw a life raft over the side, which inflated right beside the men in the water. No effort was made by any man in the water to grab hold of the liferaft. No effort was made by any of the men in the water. No apparent effort was made by any of the men in the water to reach the lines which my men had been throwing to them after the boat capsized ...

... I can only go by what my mate told me because I couldn't see the raft next to the men in the water. I couldn't see it from the maneuvering position in the wheelhouse, but I understand from the mate — on questioning the mate, he told me that the raft inflated right beside a man's shoulder and he made no attempt to grab hold of it. He said his arms were -- they seemed to be like this and didn't move (indicating) ...

... I saw a life ring with line attached landing close to the men clinging to the boat, and they didn't make any effort to reach the life ring. At this time there were some men drifting down my port side, but the lifeboat was still off the port quarter of the ship with two or three men clinging to it. It was close to my port propeller at this time, so I had to stop my port propeller in case the men got caught in it.

... At that time the SEAFORTH HIGHLANDER was forced off the location by the heavy seas, and we could no longer maintain our position alongside the men in the water or the lifeboat. Once we were clear of all the men I was able to use the port propeller again, and I maneuvered the ship back around to an upwind position from the lifeboat and steamed down close to the lifeboat, the men and the life jackets in the water. There was no sign of life at all. We could see all the men floating with their heads under the water, some of them with their arms outstretched, no sign of life, and the men on the deck were trying to pick up bodies. We couldn't get close to any of the bodies. It was very difficult. We were washing the bodies away with the motion of the ship, and for the rest of that morning we kept searching that area for any live personnel which might have been found.

... We saw many bodies in the water, bodies which had obviously not come from the lifeboat which had capsized alongside us, but there were no signs of life at all."

Captain Baxter Allingham of the NORDERTOR testified that, between 0230 and 0240:

"We got about, I would say, thirteen miles we picked up the OCEAN RANGER on radar and the two other supply vessels that were there ...

It was a fairly large target, normal target, I would say for the weather conditions and the radar being cut and I would say it was normal."

Captain Jim Davidson of the BOLTENTOR testifed that,

"At about 0245, ... We were approaching the rig from the starboard quarter, possibly just about the beam on the starboard beam of the rig. I could see from about two or three cables off, [1200-1800 feet] probably three cables off, two lights, that's all. The rest, the normal working lights were all extinguished. To the forward end of the rig there was one small white light, fairly low down near the water and at the aft end I saw one large round greenish tinged light. We didn't have a searchlight on at that time, so I can't say that these lights were on the deck, main deck level. Whether the rig was tilted forward or not, I couldn't say ...

... Later on I heard from three of or two of my crew members who had actually gone up on the lee side of my vessel from the main deck to the deck that they had been looking at the rig as we approached in the lee of the main housing and they said they could see the rig tilted forward. [Deckhand Thomas Kane estimated in a deposition to

> the USCG that the rig had a severe forward list, and that its helideck was almost touching the water]. We couldn't see this partially, I presume, because we were looking through the bridge front windows and they were covered with spray, salt, snow, et cetera, but out in the open air they said they could see the rig tilted forward, but I didn't see that ...
>
> ... They asked me from the SEDCO 706 if the rig was still upright enough to handle a helicopter on the deck. I proceeded then around the starboard quarter, around to the aft end of the rig, i.e., the downwind side of the rig for the safety of my vessel and proceeded to within about one cable [600 feet] off the stern shown by searchlights which the second officer was operating and when we were head on at the stern of the rig he had the searchlight up and shown it right across the aft end of the rig two or three times and then coming around I let the wind get on the port bow and it blew me over almost beam on the port side so I put full barrel and brought it back head to wind and swung around the other way so we had another good look at the rig and we saw the main deck of the rig from the aft end was, appeared to be horizontal, i.e., the rig appeared to be upright ...
>
> ... I thought the rig had been deballasted to some extent. The two aft legs appeared to be somewhat out of the water. The main deck appeared to be somewhat above the water more than normal but the sea conditions were very, very rough. Visibility was no good either ...
>
> ... The light definitely shown on the drilling tower which was still there and that appeared to be upright, naturally. And then I called back and said, Yes the rig is upright enough to land a helicopter on the deck. In hindsight possibly it wasn't, but from my aspect at that point, yes, it was still upright and it was still there. There were no other lights from the aft end. We could only see this greenish light that I have described and I placed that on the main deck level, just to the starboard side of midships at the aft end ...
>
> ... About that time [logged at 0255] the SEAFORTH HIGHLANDER got in contact with me on Channel 6 and said presumably after I called the 706 to tell them about the helicopter that I should proceed down to his location which was a mile, mile and a half downwind because he was alongside a lifeboat that was overturned. There were bodies in the water and if I got down there maybe I could assist."

At 0300 the sustained wind speed recorded at the SEDCO 706 was 56 knots, from 260°. Significant wave heights were recorded at 34 ft. with a period of 12 seconds. Maximum observed seas at the time were 59 ft.. Air temperatures remained between -4.5°C and -5.5°C for the rest of the day, while sea surface temperatures dropped to -2.0°C midway through the day, remaining there until late morning on February 16th.

"Around 3:00, 3:10 in the morning", according to the testimony of Captain Allingham of the Nordertor,

> "She [the OCEAN RANGER] went off the screen ... first there was nothing and then there was a couple of blips in the same area ... it was the OCEAN RANGER, I am quite sure ... within a minute they were gone ... we still had the two standby vessels on radar ..."

This was the last time that Allingham observed the RANGER on radar; shortly afterwards he called the BOLTENTOR and HIGHLANDER to see if they could observe the rig's target, and they replied in the negative.

At 0308 the HIGHLANDER reported to the 706 that there were a lot of bodies in the water, but that they showed no signs of life.

At 0322 Mobil helicopter ROL left St. John's for the RANGER site.

At 0331 the HIGHLANDER and BOLTENTOR reported to the 706 that they had seen bodies and empty lifejackets, but that recovery attempts were proving futile due to bad weather and heavy sea conditions.

Captain Allingham of the NORDERTOR testified that:

> "We arrived on the location, well about two miles to the north of the location about 3:40 in the morning and I had already informed the 706 that I wouldn't go inside the buoy pattern, not knowing how the OCEAN RANGER was situated there. So only endangering myself by going in there. So I began a search with the other two vessels."

At 0345 Mobil helicopter OKA left St. John's for the RANGER location.

At 0400 the sustained wind speed recorded at the SEDCO 706 was 55 knots, from a direction of 260°. Significant wave heights were recorded at 27 ft., with periods of 11 seconds. Maximum observed seas at the time were 49 ft. Winds and seas remained high for the rest of the day.

Search and rescue efforts continued over the next several days. Mobil helicopters ROL and OKA arrived at the scene at 0445 and 0455 respectively, and assisted in directing the three supply boats to possible lifeboat/body positions.

The lifeboat which had been alongside the SEAFORTH HIGHLANDER was never recovered in its entirety. It was, however, sighted later on February 15th. Captain Allingham of the NORDERTOR testified that:

> "Approximately 7 o'clock in the morning we found an overturned lifeboat with the life ring from the SEAFORTH HIGHLANDER attached to it ... the lifeboat was damaged ... there was a large hole in the bow of her and she was cracked down the bottom, there was a crack in the bottom. Water just passing right through and we made three attempts to recover her but all failed ... while we were involved in trying to hook a rope on here there were several bodies came out of the hole in the boat ... Approximately seven or eight, probably came out through the hole in the boat at that time ... After we got the line on her she came up, when the ship was even, she came up to our rail, it was a good view, you could see right down through the boat ... there were several bodies there strapped in by the seat belts they have in the boat. I would say a rough number of maybe twenty.
>
> While we were slapping out to wire one wire got caught in our starboard prop and stopped our starboard engine, just, we tore loose from the boat again and so taking into consideration my own ship's safety, I had to get that rectified first ... The lifeboat broke loose when it got caught in the prop ...

It drifted away, is all I can say, in that short of time [15-20 minutes]. We were going to search again for that boat, but we got a call from the aircraft search and rescue there to proceed to some liferafts, with possible life on board ... so we went to the liferafts."

The NORDERTOR's crew never saw the lifeboat again.

Search and Rescue aircraft (a fixed-wing and two helicopters) arrived at approximately 0900, and Coast Guard rescue vessels began arriving late on February 17th.

No signs of life were noted, either from individual bodies or from those sighted inside the lifeboat, after the loss of the men alongside the HIGHLANDER. During the course of search and rescue operations 22 bodies were recovered, along with two empty lifeboats (one of which had not yet been installed on its davits), part of the lifeboat which the NORDERTOR attempted to recover, four empty liferafts, and several empty lifejackets and other assorted debris. The victims who were recovered were, in general, "normally" clad; most wearing work vests and/or coveralls in addition to everyday clothes. One body was clad in a helicopter survival suit.

All victims had been wearing lifejackets; despite this, most bodies sighted were observed floating face down in the water.

5.3.3. SEDCO 706 and ZAPATA UGLAND

Early on February 14th the SEDCO 706 was located at the Nautilus C-92 well (location: 46° 51' 03"N, 48° 44' 20"W), approximately 8.5 nautical miles north-east of the OCEAN RANGER. The 706 was planning to engage in a fishing operation, weather permitting.

The ZAPATA UGLAND was located at the West Flying Foam L-23 well (location: 47° 02' 44"N, 48° 49' 17"W), approximately 20 nautical miles north of the OCEAN RANGER. The UGLAND had been attempting to hang off in anticipation of severe weather later in the day, but had become stuck in hole.

At 1430 the sustained wind speed recorded at the ZAPATA UGLAND was 61 knots, from a direction of 210°. Significant wave heights were recorded at 19 ft., with a period of 10.5 seconds. Air and sea surface temperatures were +2.0°C and 0.3°C respectively.

At 1500 the sustained wind speed recorded at the SEDCO 706 was 56 knots, from a direction of 200°. Significant wave heights were recorded at 15 ft., with a period of 9 seconds. Air and sea surface temperatures were +3.0°C and 0.5°C respectively.

Mobil Grand Banks Drilling Superintendent Merv Graham testified to the USCG that he received a call from Ken Lovell on the UGLAND at 1545. Graham continued by saying that:

> "He advised me they had hung the pipe in the lower pipe ram, sheared off the pipe, pulling the pipe out of the hole. The winds were at 100 knots, maximum combined seas 35 feet. They were getting lateral motion of four degrees off location and had disconnected the riser. The 706 had hung off and their winds were about 85 and increasing."

Rod Fraser on the 706 testified that

> "Four o'clock [1600], I believe it was, I talked to Mr. Lovell on the UGLAND ... the storm was coming on and Ken had mentioned that he sheared the pipe and they were waiting out the storm."

At around 1630, according to the testimony of Ken Lovell, the ZAPATA UGLAND disconnected from its wellhead.

At 1730 the 706 and UGLAND sent Mobil base the aviation weather report.

At 1730 the sustained wind speed at the UGLAND was recorded at 78 knots, from a direction of 230°. Significant wave heights were recorded as 31 ft., with a period of 11.4 seconds. Air and sea surface temperatures were -0.5°C and 0.6°C respectively.

At 1800 the sustained wind speed at the SEDCO 706 was recorded as 68 knots, from the direction of 225°. Significant wave heights were recorded at 29 ft., with a period of 9 seconds. Air and sea surface temperatures were 1.0°C and 0.7°C respectively.

According to the testimony of the SEDCO 706 Barge Engineer, Donald King, the 706 was hit by a large wave at "approximately 1855 to 1900". King said that

> "We were at an eighty-foot draft at that point. The wave came across our port side and we had containers tied and chained to our rail and these containers were broken free and they were moved up to forty feet across our deck and did some damage to our wind walls. We damaged a liferaft, lost one liferaft and lost an aviation fuel tank, a spare aviation fuel tank. Mostly just facial damage to our wind wall."

Keith Senkoe also discussed the wave damage:

> "Well, the wave came on the port side and we had an empty container there, it wobbled the container to the port side of the BOP house and knocked the door down. I had a fuel tank that we lost, and knocked one of the wind walls out of the BOP house and scattered a few things around there. Not too serious."

Immediately following this, at 1900, the 706 began deballasting from its drilling draft of 80 ft. to 75 ft., and disconnected from its BOP at 1910. Deballasting operations were complete by 1925.

Between 1845 and 1930 the 706 Watch Stander, Fred Hatcher, overheard what appeared to be an internal radio transmission from the OCEAN RANGER, in which a voice was heard to say that there was "water and glass on the floor down there."

At 1908 Jack Jacobson reported to Keith Senkoe that the RANGER was attempting to hang off, but was having compensator problems. He also said that a porthole had been broken out in the ballast control room, and that water and glass were being cleaned up.

At 1940 the 706 and UGLAND received NORDCO's weather forecast from Mobil base.

At 1950 Donald King on the SEDCO 706 overheard an internal radio transmission from the RANGER in which a voice he tentatively identified as Nick Dyke said he was "mopping up water and cleaning up broken glass."

Between 1950 and 2100 Fred Hatcher and Donald King overheard several internal transmissions from the RANGER:

- The RANGER's gas detection and public address systems were reported inoperational, but water and glass was still being cleaned up, and "everything looked okay."
- There was a report that "all the valves on the port side are open by themselves."
- A possibility of getting shocks off "different panels" was mentioned, and an electronics technician was called for in the control room.

At 2030 the 706 and UGLAND sent Mobil base the synoptic weather report.

At 2030 the sustained wind speed at the UGLAND was recorded at 73 knots, from a direction of 260°. Significant wave heights were recorded at 39 ft., with periods of 15.2 seconds. Air and sea surface temperatures were -2.6°C and 0.6°C respectively.

At 2100 the sustained wind speed at the SEDCO 706 was recorded as 73 knots, from a direction of 240°. Significant wave heights were recorded at 31 ft., with a period of 12 seconds. Air and sea surface temperatures were 1.1°C and 1.2°C respectively.

At 2106 a radio conversation was logged between Senkoe on the 706, Lovell on the UGLAND and Jacobson on the RANGER. Jacobson again discussed the compensator problems which led the RANGER to shear its drill string, and, according to Lovell, mentioned that water and broken glass from the broken porthole had been cleaned up in the RANGER control room.

King and Hatcher on the 706 overheard one final internal RANGER transmission between 2130 and 2145 in which Nick Dyke reported that "everything seemed to be okay" in the control room.

Donald King and Fred Hatcher on the 706 overheard the OCEAN RANGER calling the SEAFORTH HIGHLANDER to check on its condition. Time-of-occurrence estimates of this conversation vary, but Captain Duncan of the HIGHLANDER testified that it occurred around 2200.

At 2330 the ZAPATA UGLAND and SEDCO 706 sent Mobil base the synoptic weather report.

At 2330, the UGLAND recorded a sustained wind speed of 68 knots, from a direction of 280°. Significant wave heights were recorded at 32 ft., with a period of 13.6 seconds. Air and sea surface temperatures were -4.5°C and -0.3°C respectively.

At 2400 the SEDCO 706 recorded sustained wind speeds of 68 knots, from a direction of 250°. Significant wave heights were recorded as 30 ft., with a period of 11 seconds. Air and sea surface temperatures were -2.1°C and 0.0°C respectively.

At 0110, February 15th., the 706 and UGLAND overheard the OCEAN RANGER send a mayday to Mobil base. The RANGER also requested the 706 to put out mayday relays on its behalf.

At 0115 Jack Jacobson called Keith Senkoe and told him that the RANGER had a 12° forward list, and might have to be abandoned. Jacobson said he had alerted Mobil base and Search and Rescue, asking for helicopters. He requested that the standby boats from the 706 and UGLAND be dispatched to his assistance.

At 0121 the BOLTENTOR was dispatched to the RANGER.

At 0122 the NORDERTOR was dispatched to the RANGER.

At 0130 the 706 and UGLAND overheard the RANGER call Mobil base to inform them that they were going to lifeboat stations, and to request them to continue putting out maydays. Following this the 706 attempted to contact the RANGER, without success.

At 0230 the ZAPATA UGLAND recorded sustained wind speeds of 61 knots from a direction of 280°. Significant wave heights were 38 ft., with a period of 13.6 seconds. Air and sea surface temperatures were -5.2°C and -0.5°C respectively.

At 0300 the SEDCO 706 recorded sustained wind speeds of 56 knots, from a direction of 260°. Significant wave heights were 34 ft., with a period of 12 seconds. Air and sea surface temperatures were -3.0°C and 0.0°C respectively.

The ZAPATA UGLAND and SEDCO 706 were used as search and rescue support bases throughout the next day. In particular, Rod Fraser on the 706 was on-site coordinator of the Mobil search and rescue effort early in the morning of February 15th. (for details see the preceding section).

5.2.4 Mobil Base

Early February 14 normal operations were underway at Mobil base, located on the seventh floor of Atlantic Place in St. John's, with normal communications being maintained between drilling units offshore and shore-based supervisory personnel.

At 1545 Ken Lovell on the ZAPATA UGLAND reported to Merv Graham that the UGLAND had sheared its drill string.

At 1630 the OCEAN RANGER reported to Peter Kapral that the RANGER was drilling and would proceed to hang off.

Also at 1630, the radio operator at Mobil base, Christine Tavernor, received aviation weather reports from all three rigs.

At 1642 the RANGER reported to Kapral that they were attempting to hang off, but were having problems with high winds blowing their hydraulic compensator hoses out of the derrick.

At 1730 Tavernor received synoptic weather reports from all three rigs.

At 1845 Jack Jacobson on the RANGER reported to Graham that the RANGER had sheared its drill string and disconnected from the wellhead. Twenty-foot heaves were being experienced by the RANGER.

At 1930, Tavernor received a call from the weather observer on the RANGER who had called to submit weather information one hour earlier than normal, by mistake.

At 1940 Tavernor sent all three rigs the NORDCO weather forecast.

At 2030 Tavernor received synoptic weather reports from all three rigs.

At 2040, Jacobson reported to Graham via MARISAT that a wave had broken out a window in the RANGER's ballast control room, but that there was "no problem" and that water was being mopped up. Jacobson said that "all of the equipment was functioning properly", and that anchor tensions were in the 240,000 pound range. Winds were in the 90 to 100 knot range, and maximum combined seas were over 50 feet. Graham requested that Jacobson check the other rigs' condition and report back to him.

At 2215, Jacobson reported back to Graham as requested. He reported that at the RANGER, maximum combined seas were 55 to 65 ft.. He said that "all of the equipment [in the control room] was functioning normally." Jacobson also reported that at the UGLAND they had lost one guideline and that winds were 80-85 knots, with maximum combined seas of 35-55 ft.. The 706, he said, had disconnected and had its thrusters on 75 percent power. Jacobson and Graham agreed that "the rigs were all riding out the storm with no problems".

At 2330 the radio operator at Mobil base, Richard Flynn, received synoptic weather reports from all three rigs.

At 0100 on February 15th Graham received a MARISAT call from Jacobson. Jacobson reported that the RANGER was listing to the bow "eight to ten feet", which was taken to mean degrees, and didn't know what the problem was. He reported winds of 75 to 80 miles per hour, and asked that Graham alert the Coast Guard. Graham replied that he would do so, and send work boats and helicopters to the RANGER's assistance.

At 0105 Graham called the Coast Guard and advised them of the RANGER's situation.

At 0110 Graham called Ken Beattie (Logistics Supervisor, Mobil Base), advised him of the situation, and told him to prepare Mobil's helicopters.

Also at 0110, Richard Flynn received a Mayday call from the radio operator on the OCEAN RANGER, who said that the RANGER was listing badly, and asked Flynn to notify Search and Rescue. The 706 also picked up this message and began transmitting Mayday relays. At the same time Jack Jacobson came on, repeated the previous message, and said they "were going to want to evacuate". Flynn then patched Jacobson into Search and Rescue. Jacobson informed them that the RANGER was listing badly and wanted to evacuate, and requested Chinook helicopters. Flynn then notified Tom Dossett (Administrations Manager, Odeco), who said he would notify Jimmy Counts (Drilling Superintendent, Odeco). Following this, Flynn telephoned Jack Squires (Mobil airport manager) at home and informed him of the RANGER's situation. Squires then left to get the helicoptor crews and arrange for the readying of the helicopters.

At 0120 Graham called Flynn and told him to instruct Rod Fraser on the 706 to release the BOLTENTOR and NORDERTOR to go to the RANGER's assistance. Graham then left his home to go to Mobil's office in Atlantic Place.

At 0130 the RANGER called Flynn, and asked him to continue putting out Maydays, as the RANGER was going to lifeboat stations.

At 0145 Graham arrived at Mobil's base; shortly afterward, Steve Romansky (Operations Manager, Mobil), Jim Mounteer (Engineering Supervisor, Mobil), Counts and Dossett also arrived.

At 0153 Graham called Rod Fraser to inquire about the status of the SEAFORTH HIGHLANDER.

At 0200 Fraser reported to Graham that the HIGHLANDER was about two miles from the RANGER and had it on radar, but had not yet sighted it. The BOLTENTOR was reported to be 4.6 miles away, and the Nordertor three hours away.

At 0207 Air Search and Rescue advised Romansky that they couldn't fly from Gander at that time.

At 0220 Ken Beattie reported to Graham that Mobil's helicopters should be in the air by 0300.

Merv Graham testified that he received a call at:

"0230 hours Rod Fraser, SEDCO 706 to Merv Graham. The SEAFORTH HIGHLANDER had advised Rod that he was alongside a lifeboat. I advised Rod to contact the skipper on the HIGHLANDER and not attempt rescue if the lifeboat was intact nor try to take it in tow as per the experiences encountered with taking a lifeboat in tow in the Gulf of Mexico and with the loss of life of nearly all of the occupants as documented in a letter in our files".

Fraser testified that "He [Graham] said inform or pass on to the boats not to go too close to the lifeboats because of the possibility of a collision...

"I was in the radio control room relaying information to the radio control operator and back to town, but I told the radio operator to forward it on to the SEAFORTH HIGHLANDER, to the boats" ...

Fraser testifed that he heard the 706 radio operator relay this message to the HIGHLANDER, and heard the HIGHLANDER acknowledge the message.

However, Baxter King, the radio operator at the time on the 706, testified when questioned about this message that "I didn't hear anything of that nature, sir, no", and Captain Duncan of the HIGHLANDER testified that "At no time did we receive any instruction not to attempt to rescue. Under these conditions had we received such an instruction I would have questioned the morality behind it."

At 0235 Fraser reported to Graham that the lifeboat alongside the HIGHLANDER had capsized, that there were men in the water, and that the HIGHLANDER was attempting rescue. The BOLTENTOR was approximately one mile from the scene, and could see many lifejacket lights in the water.

At 0255 Fraser told Graham that the BOLTENTOR had reported the RANGER was level enough for a helicopter to land on. The HIGHLANDER and BOLTENTOR were nearby attempting to pick up men from the water.

Mobil base continued to monitor communications from the disaster scene and to receive updates from the 706 throughout the remainder of the search and rescue operation.

Table 5.1 Sequence of Events

1545——KL-MG: ZU had sheared and disconnected riser in 100 knot winds, 35ft. Seas. 706 had hung off.

1600——RF-KL: KL mentioned ZU had sheared.

1630——CT received aviation weather from all 3 rigs.
ZU finished disconnecting.
PK-OR: OR was drilling and would proceed to hang off.

1642——OR-PK: OR was hanging off; had problems with compensator hoses being blown out of derrick.

1730——CT received Synoptic weather from all 3 rigs.

1845——JJ-MG. OR had sheared and disconnected

1855——Large wave broke over 706 causing some damage on deck. 706 disconnected, deballasted 5ft. to 77ft. draft. Deballasting operation took 20 minutes

[illegible]——ET-JC: OR had sheared and was waiting on weather.

1845--1930——FH overboard internal OR transmission-- "water and glass on the floor down there."

1900——KS-JJ: OR attempting to hang off, but hoses blowing into derrick and fouling. Window out in control room, water and glass being cleaned up.

1930——CT received call from OR weatherman Ibr. early (by mistake).
ZU hit by 75' wave

1940——CT sent all three rigs NORDCO weather

1950——DK overboard internal OR transmission. N.Dyke was "mopping up water and cleaning up glass"

1950--2100——FH and DK overboard internal transmission from OR; gas detection and PA systems knocked out; valve(s) were operating on their own; possibly getting shocks off different panels; requested ET in control room.

2030——CT received synoptic weather from all three rigs

2040——MG-JJ: 90-100 knot winds and 50ft. seas at OR. JJ said wave broke out window in control room; mopping up, no problem. All equipment functioning normally. Anchor tensions in 240,000 lb. range. JJ would check other rigs condition.

2105——JJ-KL-KS: JJ mentioned he had had to shear due to compensator problems, porthole had been broken and water and glass cleaned up in control room; had not pumped up to survival draft.

2100--2200——OR-SFH: OR checking SFH's condition - SFH OK

2100--2200——Bolt overboard internal OR transmission: "broken glass ... water in here get it cleaned up high powered cables down there mention of valves opening and closing that should not be operating.

2130--2145——FH and DK overboard internal OR transmission (N.Dyke) " evything OK I am going to get her all cleaned up.

2215——JJ-MG: 55-65ft. seas at OR. JJ reported all equipment functioning normally, 706 had disconnected and had thrusters on 75% power. ZU lost one guideline. 90-95 knot winds, 35-55ft. seas at ZU. JJ and MG agreed rigs riding out storm with no problems.

2330——RFI received weather report from all three rigs.

0100——JJ-MG: (MARISAT) JJ reported OR to bow 8-10 ft. (°) 75-80 mph winds. Attempting to isolate problem but did not know what it was. Asked MG to alert CG. MG said work boats and helicopters would be on the way.

0105——OR-SFH: Requested SFH to come to Close standby; OR had list to port and all countermeasures ineffective. SFH 8miles from OR.

0105——MG-CG: Advised CG of OR situation...

0109——OR sent out Mayday on COMSAT; reported list of 12° and progressing to port side: W winds of 75 knots.

0110——MG-Ken Beattie: Advised him of OR situation and told him to prepare helicopters.
OR-RFI: requested Mayday; OR listing badly. Told RFI to notify SAR. RFI did so.
JJ-RFI: reported OR's message and said he would want to evacuate.

0115——JJ-KS: Said OR had 12° forward list. JJ suspected he might have to abandon. Said he had alerted CG and mobil base and has requested helicopters. Requested 706s and ZUs work boat.

0121——Boltentor was dispatched to OR location.

0122——Nordertor received Mayday from OR, received clearance from ZU and left for OR location.

0130——OR-RFI: OR going to lifeboat stations. 706 then attempted to contact OR without success.

0207——SFH sighted lume of OR. OR seemed normal and fully illuminated. SFH then spotted many flashing lights in water. SFH could not tell if OR was listing.

0214——SFH reported it was going to a flare.

0217——SFH spotted life boat.

0230——MG-RF: SFH alongside lifeboat. MG told RF to instruct work boats not to get too close to lifeboats because of danger of collision. RF says he relayed this. RD says he did not receive it.

0235——Lifeboat overturned after SFH attempted to get a line aboard. 60ft. waves, 90mph winds, freezing snow.

0230--0240——Nordertor picked up OR on radar as a "normal target"; also Boltentor and SFH were on screen <1 mile astern and 1 1/2 miles downwind respectively. Nord 13 miles from OR.

0235--0245——Bolt approached OR from stbd. 1/4; All OR working lights off; One small white light fwd. near waterline; one large greenish light on aft end of main deck stbd. of midships. No sign of life. Bolt came within one cable of aft end. JD said deck seemed level enough to land on with helicopter. OR appeared deballasted.

0250——RF-MG: SFH attempting to pick up personnel in water. OR O.K. for helicopters to land on. SFH and Bolt near OR attempting rescue.

0300--0310——OR disappeared from Nord's radar; reappeared as "a couple of small blips," then disappeared for good.(elapsed time one minute) Bolt and SFH were still on radar.

0322——Mobil helicopter ROL left St. John's.

0325--0335——Nord - Bolt: Nord asked if OR was still on Bolt's radar. It was not.

0340——Nord arrived at OR location; (~2 miles N) Did not enter buoy pattern. Joined Bolt and SFH in SAR operations.

0345——Mobil helicopter OKA left St. John's.

Table 5.1A

List of Abbreviations & Glossary of Names and Positions

Vessels and Organizations

OR - OCEAN RANGER
ZU - ZAPATA UGLAND
706 - SEDCO 706

SFH - SEAFORTH HIGHLANDER (standby vessel for OCEAN RANGER)
Bolt - BOLTENTOR (standby vessel for SEDCO 706)
Nord - NORDERTOR (standby vessel for ZAPATA UGLAND)
USCG - United States Coast Guard
CG - Canadian Coast Guard
SAR - Search and Rescue
Mobil - Mobil Oil Canada, Limited
ODECO - Ocean Drilling and Exploration Company

OCEAN RANGER

JJ — Jack Jacobson - Mobil drilling foreman
Bob Madden - Mobil drilling foreman
KT - Kent Thompson - ODECO Toolpusher
Domenic (Nick) Dyke - Junior ballast control room operator

SEDCO 706

RF - Rod Fraser - Mobil drilling foreman
KS - Keith Senkoe - Mobil drilling foreman
DK - Donald King - Barge engineer
FH - Fred Hatcher - Watch stander
BK - Baxter King - Radio operator

ZAPATA UGLAND

KL - Ken Lovell - Mobil drilling foreman

SEAFORTH HIGHLANDER

RD - Ronald Duncan - Captain

BOLTENTOR

JD - Jim Davidson - Captain
James Eby - Chief Engineer
Thomas Kane - Deckhand

NORDERTOR

Baxter Allingham - Captain

Table 5.1A (Cont'd)

Mobil Base, St. John's

MG - Merv Graham - Grand Banks Drilling Superintendent
PK - Peter Kapral - Senior Mobil drilling foreman
CT - Christine Tavernor - Radio operator
RF1 - Richard Flynn - Radio operator
Steve Romansky - Operations manager
Ken Beattie - Logistics supervisor
Jim Mounteer - Engineering supervisor
Jack Squires - (Mobil) Airport manager

ODECO

JC - Jimmy Counts - Drilling Superintendent
Tom Dossett - Administrations Manager

Table 5.2 Environmental Conditions, February 12 - 15, 1982

Date & Time	Bar. Press. (mb)	Vis. (n.mi.)	WINDS Sust. Speed (knots)	WINDS Dir'n (°True)	WIND WAVES Sig. Height (feet)	WIND WAVES Period (sec)	SWELL WAVE Height (feet)	SWELL WAVE Period (sec.)	SWELL WAVE Dir'n (°True)	Max. Obs. Wave (ft.)	Air Temp. (°C)	Sea Temp. (°C)
12/2330	1009	5-11	34	270	8	7	-	-	-	-	-2.5	-0.8
13/0230	1012	1-2	40	310	11	7	-	-	-	-	-2.7	-0.7
0530	1018	5-11	37	300	11	8	-	-	-	-	N.A.	-0.7
0830	1023	2-5	32	300	16	9	-	-	-	-	-5.6	-0.6
1130	1026	11-27	21	300	15	9	-	-	-	-	-6.0	-0.6
1430	1028	11-27	17	300	11	8	-	-	-	-	-6.0	-1.2
1730	1029	11-27	14	290	11	6	-	-	-	-	-6.4	-1.5
2030	1029	11-27	4	290	2	2	7	8	290	-	-6.2	-1.6
2330	1027	11-27	4	200	0	-	8	10	290	-	-5.2	-1.2
14/0230	1020	11-27	29	130	5	5	7	9	280	-	-4.3	0.0
0530	1012	0.03-01	41	110	2	5	5	7	270	-	-3.5	-1.7
0830	999	0.3-0.5	44	100	10	7	-	-	-	-	-1.5	-0.5
1130	985	2-5	47	130	15	8	-	-	-	28**	1.2	0.5
1430	978	0.5-1	67	210	15	9	10	9	130	30	2.5	0.5
1730	974	0.3-0.5	72 (88)*	220	31	9	-	-	-	47	-1.0	0.6
2030	974	0.3-0.5	72	240	33	12	-	-	-	61	-2.2	0.6
2330	983	0.3-0.5	58	270	33	11	23	9	230	61	-4.5	-0.7
15/0230	985	1-2	61 (75)	280	30	10	-	-	-	62	-5.2	-0.5
0530	992	1-2	56 (69)	280	26	12	-	-	-	62	-5.5	-0.5
0830	996	2-5	52	280	30	12	-	-	-	-	-6.2	-0.8
1130	999	2-5	49	280	28	10	-	-	-	-	-6.0	-1.0
1430	1002	2-5	52	290	26	10	-	-	-	-	-5.6	-1.4
1730	1006	2-5	49	290	25	10	-	-	-	-	-6.0	-1.8
2030	1009	2-5	43	290	21	10	-	-	-	-	-6.2	-1.8
2330	1009	11-27	38	300	20	10	-	-	-	-	-6.8	-2.0

* Values in parentheses are maximum gust values recorded in the preceding 3-hour period (from ZAPATA UGLAND)

** Maximum observed wave values are from the ZAPATA UGLAND

CHAPTER 6 MOST PROBABLE CAUSES OF THE SINKING OF THE OCEAN RANGER

6.1 Introduction:

There are two main aspects of the sinking of the OCEAN RANGER; the development of the initial list and the subsequent events which led to the capsize. The present investigating team has assembled what it considers to be the information most relevant to the explanation of these aspects.

The main facts are given for a particular event or series of events followed by a 'most probable' interpretation. The cumulative interpretations are in essence the 'most probable' causes of the accident.

It should be borne in mind that the objective is to determine most probable cause. Obviously, various interpretations could be made of the facts presented. The investigating team, having examined every reasonable interpretation, has concluded that the interpretation herein is both the most logical one and the one which draws most support from the evidence and analyses performed.

6.2 Damage to Portholes

6.2.1 Facts:

It has been established by diving survey (Appendix 2) that the glass in two portholes (numbers 1 and 2) in the ballast control room was broken.

From testimony, it has been determined that a porthole had been broken out prior to 1908 NST.

At 2040 NST, the OCEAN RANGER reported to Mobil base that a wave had broken a porthole in the control room.

At 2106 NST, the OCEAN RANGER, in conversation with the SEDCO 706 and the ZAPATA UGLAND, reported (Section 5.3.1) that " ... the window had been knocked out ... they were taking on some water, but they had mopped it up and there was no problem."

At 2030 NST, the relevant environmental conditions were:

Wind	72 knots	sustained
Waves	33 ft.	significant height
	61 ft.	maximum height
	240°	direction

The rig heading was 310° true.

The control room was located in column SC-3. The portholes were located approximate 30 ft. above mean sea water level when the rig was at an 80 ft draft. The layout of the control room (Figure 4.1.C) was such that porthole 2 was highly susceptible to wave impact given the particular wave height and direction and rig orientation. Porthole 1 was susceptible to impact but not to the same extent as porthole 2.

6.2.2 Interpretation:

It is likely that porthole 2 was broken by wave action and that water entered the ballast control room at that point. Porthole 1 may have been broken by wave action or by some other means during subsequent capsizing of the rig.

6.3 Water Damage to Ballast Control Panel

6.3.1 Facts:

Between 1950 NST and 2100 NST , conversations on the OCEAN RANGER were overheard by the SEDCO 706 to the effect that 'they were mopping up water and cleaning up broken glass. In this time frame from ten to eight until nine, a little after nine, we picked up two or three different conversations. One being the broken glass and water, another being that their P.A. system was knocked out. Their gas detection system was knocked out, everything appeared to be okay. They were cleaning, they said everything looked okay. "We are still cleaning up water." Sometime after 9 o'clock we heard they were getting shocks off different panels and they wanted the E.T. man, electronic technician to come down to the control room" ... " all the valves on the port side [were] open by themselves".

The layout of the ballast control room was such that the ballast control panel was located near porthole 2 (spanning portholes 3 and 4).

6.3.2 Interpretation:

Water coming in through the broken porthole 2 struck the ballast control panel. Some water likely entered the panel and caused shorting of switches and possibly other parts of the electrical system. The shorting of switches and relays may have caused (1) a valve or valves to open on their own; and/or 2) the actual position of a valve or valves to be uncertain to the operator because of a malfunction of the indicator system.

Any salt remaining inside the ballast control panel after the water had dried could also have caused unpredictable and unreliable behaviour of the panel resulting in the malfunction of valves and/or valve position indicators.

6.4 Early Status Report

6.4.1 Facts:

At approximately 2040 NST, the OCEAN RANGER reported to Mobil in St.

John's that a wave had broken a window in the rig's control room, but that they were mopping up, and that there was no problem.

Between 2130 and 2145 NST, an internal OCEAN RANGER report was overheard by the SEDCO 706 to the effect that everything in the control room was okay and that it had been all cleaned up.

At 2215 NST, the OCEAN RANGER reported to Mobil in St. John's that "the maximum combined seas were in the 55 foot, the odd wave going up in the 65 foot range." With respect to the ballast (barge) control room, the OCEAN RANGER reported that "all of the quipment was functioning normally". The OCEAN RANGER reported as well on the status of the other rigs, the SEDCO 706 and the ZAPATA UGLAND, and the OCEAN RANGER and Mobil in St. John's were "both in agreement at that time that the rigs were all riding out the storm with no problems" and that "all that we could do was ride the storm out for the night" and that Mobil in St. John's would talk to them in the morning.

6.4.2 Interpretation:

At 2215 NST, the personnel on the OCEAN RANGER did not believe that there were any serious problems with the ballast control system. It is likely that, at this time, the rig was maintaining a level trim. It is likely that the ballast control panel had been shut down temporarily while there had been problems earlier in the evening but that it was fully powered and in its normal operational mode at this time.

It is likely that at this time some amount of water or salt precipitate was still present either on or in the ballast control panel.

6.5 Weather Report

6.5.1 Facts:

At 2330 NST the OCEAN RANGER transmitted the usual synoptic weather report to Mobil base. Winds were recorded at 58 knots and significant wave heights at 33 ft. Air and sea surface temperatures were recorded as -4.5°C and -0.7°C, respectively.

There was no communication from the OCEAN RANGER between 2215 NST February 14 to 2330 NST February 14.

6.5.2 Interpretation:

Since nothing unusual was reported in the weather report from the OCEAN RANGER, it is possible that there were no serious problems with rig stability at that time that may have been apparent to the weather observer who was positioned in the pilot house. It should be noted that the weather observer did not have any responsibility to report unusual events regarding the rig's stability. In fact, there had been no mention of the February 6, 1982 listing incident in the weather reports issued subsequent to that incident.

The fact that there were no communications during the period 2215 NST February 14 to 2330 NST February 14th indicates that there were no ongoing problems with stability or ballast control or at least none that the personnel did not feel they could handle. It is also likely that personal communications to shore were curtailed during this period.

6.6 Development of the List and Mayday

6.6.1 Facts:

At 0100 NST February 15, the OCEAN RANGER reported on MARISAT to Mobil in St. John's that the rig was listing to the bow 8 to 10 feet (understood by Mobil in St. John's to mean degrees). They did not know what the problem was. The OCEAN RANGER requested that the Coast Guard be alerted to their situation. Mobil in St. John's acknowledged and replied that work boats would be on the way and that Mobil's helicopters would be activated.

At 0105 NST, the OCEAN RANGER called its standby vessel, the SEAFORTH HIGHLANDER, and requested that it come to close standby; when asked the reason, the OCEAN RANGER replied that the rig had a list to port and that all countermeasures were ineffective.

At 0109 NST, the OCEAN RANGER sent out a Mayday on MARISAT: "WE ARE THE ODECO OCEAN RANGER KRTB LOC 46.33 N 48.50.13 W AND ARE EXPERIENCING A SEVERE LIST OF ABOUT 10-15 DEGREES AND ARE IN THE MIDDLE OF SEVERE STORM AT THE TIME 12 DEGREES AND PREGRESSING .. REQUEST ASST ASAP.. WE ARE AN OFFSHORE DRILLING PLATFORM ..."

At 0110 NST, the OCEAN RANGER requested a Mayday in a transmission on Channel 6 received by the SEDCO 706. The 706 immediately began transmitting Mayday relays on Channel 2182.

At the same time, the OCEAN RANGER called Mobil base and advised that they had a Mayday, that the rig was listing badly, that Mobil base was to notify Canadian Coast Guard Search and Rescue, and that they were going to want to evacuate. Mobil base had Search and Rescue on the phone between 0110 and 0130 and phone patched them into the OCEAN RANGER. The OCEAN RANGER did not give any details. They just said they were listing badly, wanted to evacuate and they wanted three or four helicopters, Chinooks to come out and take them off.

At 0115 NST, the OCEAN RANGER reported to the SEDCO 706 that the rig had a twelve degree forward list and that they were suspecting that they were going to have to abandon ship. The SEDCO 706 was requested to send its workboat, the BOLTENTOR, and the ZAPATA UGLAND's workboat, the NORDERTOR, to the OCEAN RANGER.

At 0130 NST, the OCEAN RANGER called Mobil base and informed them they were going to lifeboat stations. This was the last transmission received or overheard from the OCEAN RANGER.

From the analysis and investigations carried out in this investigation, the following results are particularly pertinent to these events:

1. As shown in Sections 4.4.3.2 and 4.4.3.4, the ballast control panel was vulnerable to malfunction if salt water entered it. The malfunction could manifest itself in a valve or valves opening on their own. If certain valve/valves malfunctioned, there could be a transfer of ballast (Section 4.2.3.

2. Based on the ballast configuration prior to the incident and the results of the Royal Commission Diving Survey (Appendix 2), it is evident that port tank WB10 was 100 percent full initially and is 2 percent full after capsize.

   Conversely, the February 14th configuration shows that port WB4 was 4 percent full and the after capsize configuration shows it to be 100 percent full.

   The February 14th configuration shows that port FO12, starboard FO12 and DW13 were 26 percent, 36 percent and 36 percent full, respectively. The present configuration shows them to be 93 percent, 86 percent and 86 percent full, respectively. It has been shown in Section 4.2.1.4.3 that there is a way to transfer sea water into the fuel oil tanks, through the upper deck fill lines.

3. Calculations show that in still water conditions at a draft of 80 ft. flooding from port tank WB10 to port WB4 could cause a bow list of approximately 5 degrees in one hour and approximately 10 degrees in two hours.

   Calculations also show that flooding from port tank WB10 to port WB1 could cause a bow list of approximately 5 degrees in thirty minutes and approximately 10 degrees in one hour forty-five minutes.

4. The indication of operational status of the ballast system (see Section 4.4.3.3) was such that the ballast control operator could not have distinguished between a faulty valve or a faulty limit switch.

5. The ballast configuration prior to the incident shows that there was little ullage in the aft ballast tanks. That is, if the rig was down by the bow, it would be difficult to return to level trim through addition of ballast to the aft tanks. The operational alternative would likely have been to attempt to pump out the forward ballast tanks.

6. Calculations carried out (Section 4.2.3.3) show that it may not have been possible to pump out the forward ballast tanks if the rig was down about 10° by the bow.

6.6.2 Interpretation:

There had been no communications of any kind from the OCEAN RANGER for some time prior to the Mayday call at 0100 NST on February 15. This would indicate that there was no perceived ongoing problem with either stability or the ballast control system. Also, the fact that the OCEAN RANGER personnel did not isolate the problem indicates that it was not ongoing. These facts and the rapid sequence of events indicate that an initial bow list of about 5 degrees could have developed quickly, within a time period of an hour or less.

The list likely developed because of a malfunction of the ballast control system arising from water and/or salt present on or in the ballast control panel as a result of the incident early in the evening of February 14, that is, the breaking of a porthole by a wave.

The control panel switches likely malfunctioned and one or more valves opened inadvertently and water was transferred from a middle or aft ballast tank in the port pontoon to a forward ballast tank. Based on the ballast configuration before and after the accident, a possible transfer would have been from port WB10 to port WB4. If an attempt was made to pump out WB4, the pumping system would not likely have performed effectively. Water may have been added to port FO12 and starboard FO12 and DW13 in an attempt to correct the list. Such an action would increase the draft beyond 80ft.

Port WB1 and starboard WB1 would likely have had ingress of water due to damage to the hull after capsizing took place. (The February 14th configuration shows both tanks empty. The present configuration shows both tanks full).

There is also the possibility that water may have entered some tanks from the sea and/or that water may have transferred from one tank to another during and/or after sinking.

It is possible that the ballast control panel would have been shut down after a problem was noticed. This action should have caused all valves to failsafe close. The list at this time could possibly have been 5-7°. In order to attempt to fix the problem, the panel may have been brought back on with the result that the transfer of ballast forward would have continued ultimately resulting in the 10°-15° list reported in the 0110 NST Mayday. It is likely that the panel would have been shut down permanently by this time. It appears that full power was still available on the rig.

The manual control of the valves was described in Section 4.4.3.5.(d). Pertinent results of the diving survey conducted in July, 1982 by the Royal Commission into the OCEAN RANGER Disaster are presented in Appendix 2. They show that brass control rods had been inserted in positions controlling certain valves. The present investigating team can find no logic to explain why these valves in particular may have been activated. A possible explanation is that the rods were inserted on a general instruction and that there was no set plan for their usage prior to insertion. It is unlikely that the operation of these particular valves would have caused an improvement in the situation. It is unlikely that their operation was a significant contributory factor to the initial development of the list, although their operation may have contributed to the progression of the list and the subsequent capsizing.

It has been suggested that the ballast control officer on the OCEAN RANGER believed that insertion of the brass rods would close valves rather than open them. This is questionable. The ballast control officer should have been fully aware that shutting down the ballast control panel (ie. cutting power to it) would cause the valves to failsafe close. Since the valves would have already been closed (making the assumption that power would have been cut to the ballast control panel), there would be no reason to insert the rods to close valves.

6.7 Capsizing of the OCEAN RANGER

6.7.1 Facts:

At approximately 0150 NST (logged by the SEDCO 706 at 0207), February 15, the OCEAN RANGER's standby boat, the SEAFORTH HIGHLANDER, made visual contact with the OCEAN RANGER, approaching from the stern. The rig appeared to have all lights on. It was not possible for the SEAFORTH HIGHLANDER to ascertain if the rig was listing because of the motion of the standby boat itself in the high winds and waves.

At this time, the SEAFORTH HIGHLANDER spotted many small lights in the water downwind of the rig. Shortly after, a red distress flare was sighted approximately three cables (1800 ft.) downwind of the rig.

At 0221 NST, the SEAFORTH HIGHLANDER reported being alongside a lifeboat from the rig near the flare location.

Between 0230 NST and 0240 NST, the ZAPATA UGLAND's standby boat, the NORDERTOR, observed the OCEAN RANGER on radar as a normal target. The SEAFORTH HIGHLANDER and the SEDCO 706's standby boat, the BOLTENTOR, were also visible on the radar one and one half (1 1/2) miles downwind of the rig and less than a mile astern of the rig, respectively.

Between 0235 NST and 0245 NST, the BOLTENTOR approached the OCEAN RANGER from three cables (1800 ft.) off the starboard quarter. There was no sign of life or of activity on the deck of the rig. The only lights on were one small white light forward near the waterline and one fairly large greenish light on the aft end of the main deck starboard of midships. The BOLTENTOR steamed around to the stern of the rig and approached to within one cable (600 ft.).

The Captain of the BOLTENTOR testified that from the stern, the aft columns appeared somewhat higher out of the water than normal but that the rig seemed to be level. Two crew members on the deck of the BOLTENTOR told the Captain later that the rig was tilted forward as they viewed it while approaching from the starboard quarter. One crew member in a deposition to the U.S. Coast Guard, estimated that the rig had a significant forward trim, and that the helideck was intermittently immersed.

Between 0300 NST and 0310 NST, the OCEAN RANGER disappeared from the NORDERTOR's radar. The Captain of the NORDERTOR testified that in the space of about one minute, the image of the rig disappeared from the radar screen, reappeared briefly as two oval blips, then disappeared for good. The images of the other two standby boats were still on the screen.

At approximately 0300 NST, the sustained wind speed recorded at the SEDCO 706 (8.5 miles NE from the OCEAN RANGER) was 56 knots, and significant wave heights were 34 ft., with maximum wave heights of 59 ft. The air temperature was approximately -5°C.

From the analyses and investigations carried out in this study and others, the following results are particularly pertinent to these events:

1. The OCEAN RANGER after sinking was found to be upside down with its bow headed 110° true (Appendix 2).

2. Eight of the mooring lines appeared connected; the remaining four were broken (Appendix 2).

3. Analyses carried out by the U.S. Coast Guard (Appendix 4) show that for the OCEAN RANGER with the sea conditions existing on the night of the accident

    - at an 80 ft. draft and about a 15° port bow list, there would be flooding of the port bow chain locker.

    - flooding of the port bow chain locker would occur for combinations of draft and list as follows: 85 ft. draft and about a 13° port bow list; 90 ft. draft and about a 12.5° port bow list; 95 ft. draft and about a 10° port bow list.

4. Analysis of chain locker flooding carried out by the U.S. Coast Guard (Appendix 4) shows that, to reduce the freeboard to 21.5 ft. (It was assumed that the upper hull would be immersed at this freeboard, resulting in flooding and capsize),

    - At an initial list angle of 15° and a draft of 80 ft., it would take about three and a half (3 1/2) hours.

    - At an initial list angle of 15.5° and a draft of 85 ft., it would take about two and a half (2 1/2) hours.

    - At an initial list angle of 14.0° and a draft of 85 ft., it would take about one and a half (1 1/2) hours.

5. Static stability analysis (Appendix 1) indicate that flooding the forward chain lockers would immerse the upper hull and if the upper hull is not buoyant it would result in capsizing.

6.7.2 Interpretation:

By 0109 NST on February 15,, 1982, the OCEAN RANGER had developed a port list of 10°-15°. This was a sufficiently severe list under the existing wave conditions to initiate downflooding of the forward port chain locker. The increase in forward trim also caused the forward starboard chain locker to flood.

The progressive flooding eventually gave the rig such a forward trim that, by approximately 0245 NST, the helideck was intermittently immersed.

Both the forward chain lockers continued to fill causing the upper hull to be immersed and flooded. This brought the rig to an unstable position and it capsized.

The momentum of the rig and the increased wave forces during capsize caused the breakage of the forward mooring lines. Due to the size of the rig and the water depth, the forward ends of the pontoons likely scraped the seafloor damaging the anchor bolsters and forward trim tanks. Breakage of the forward mooring lines drew the rig downwind toward the intact mooring lines until the rig settled upside down on the bottom.

Volume

2

GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

Technical Investigation

of

Ocean Ranger Accident

Volume 2

(Appendices)

PETROLEUM DIRECTORATE
APRIL 1983

ISSUED UNDER THE AUTHORITY
OF

THE HONOURABLE WILLIAM W. MARSHALL, Q.C.
MINISTER

TECHNICAL INVESTIGATION
OF
OCEAN RANGER ACCIDENT

VOLUME II

(APPENDICES)

APPENDIX 1

Lloyd's Register of Shipping

OCEAN RANGER INVESTIGATION

FINAL REPORT

to the

Petroleum Directorate

OSG/5195

'OCEAN RANGER' INVESTIGATION

FINAL REPORT

MARCH, 1983

Lloyd's Register of Shipping Offshore Services Group

OSG/3195

'OCEAN RANGER' INVESTIGATION

FINAL REPORT

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MARCH, 1983

Lloyd's Register of Shipping Offshore Services Group

'OCEAN RANGER' INVESTIGATION

PART I

BALLAST CONTROL SYSTEM STUDIES

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MARCH , 1983

'OCEAN RANGER' INVESTIGATION

BALLAST CONTROL SYSTEM STUDIES

THIS REPORT SUMMARISES THE MAIN RESULTS AND CONCLUSIONS FROM THE SOCIETY'S STUDIES OF THE 'OCEAN RANGER'S' BALLAST CONTROL SYSTEM.

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'OCEAN RANGER' INVESTIGATION

PART IA

REPORT ON MECHANICAL ENGINEERING ASPECTS OF THE BALLAST SYSTEM

Lloyd's Register of Shipping **Offshore Services Group**

"OCEAN RANGER" INVESTIGATION

Report on Mechanical Engineering Aspects of The Ballast System

1. Introduction

The plans as listed in Appendix A have been appraised from the mechanical aspects in respect of good engineering practice and accepted principles among the criteria for which we include the Society's Rules.

In the course of our appraisal, consideration has been given to:

a) Ballast Piping System
b) Ballast Pumps
c) Ballast System Operational Failure.

2. Ballast Piping System

The ballast piping system in each pontoon is identical, the only cross-connection between the two systems being via a single ballast pump discharge line across the cellar deck.

The ballast piping system in each pontoon consists of three inter-connected pipelines:-

a) Ballast Main
b) Ballast Suction Main
c) Ballast Discharge Main

2.1 Ballast Main

This line is the connecting pipeline for all the individual ballast tank branch lines, each branch being connected to the Ballast Main via a remote operated butterfly valve.

2.2 Ballast Suction Main

This line has directly connected to it the ballast main, the three ballast pump suctions, the sea suction chest and three emergency bilge suctions, all connected via remote operated butterfly valves.

2.3 Ballast Discharge Main

This line has directly connected to it the ballast main, the three ballast pump discharge lines and the overboard discharge line, all connected via remote operated butterfly valves.

2.4 Piping Systems Interconnection

2.4.1 Bilge

The ballast system is not connected to the Bilge System. The ballast suction main is however fitted with three emergency bilge suctions directed to the following spaces:-

a) Pump Room
b) Propulsion Room
c) Pump Room Void Space

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2.4.2 Drill Water

The drill water system in each pontoon is connected to the ballast system via the following cross-connections:-

a) Between the drill water suction main and the outboard ballast pump suction chest in the pump room.

b) Between the drill water discharge main and the outboard ballast pump discharge in the pump room.

2.4.3 Fuel Oil

There are no cross-connections indicated between the fuel oil and either the ballast or the drill water systems.

2.5 Valves

2.5.1 All ballast, drill water and fuel oil tank isolating valves for pontoon tanks are located in the pump room.

2.5.2 All the valves incorporated in the ballast system are remote operated butterfly valves. The operation of the valves is 'air open - spring close', except for the following which are manually operated:-

a) The sea chest isolating gate valve which duplicates the sea-water suction remote operated butterfly valve to the ballast suction main.

b) The ballast system overboard discharge screw-down non-return valve which duplicates the overboard discharge remote operated butterfly valve.

2.6 Air Pipes

All air pipes from the tanks in the pontoons are routed through the columns to the cellar deck. All air pipes terminate with air pipe vent heads.

2.6.1 Air Pipe Vent Heads

All vent heads are fitted with float plugs. The float plugs will seal off the vent heads to prevent flooding if the vent heads should become submerged in upright or normal trimmed conditions.

2.7 Piping

The piping arrangements for the ballast system are such as would be accepted by the Society under the Rules for the Classification of Ships.

2.7.1 All ballast piping material is of carbon steel.

3. Ballast Pumps

3.1 Location

Three ballast pumps are located in each pontoon, the location being as follows:

/......

a) Port Pontoon

No. 1 Ballast Pump	Pump Room outboard side
No. 3 Ballast Pump	Pump Room inboard side
No. 5 Ballast Pump	Propulsion Room

b) Starboard Pontoon

No. 2 Ballast Pump	Pump Room inboard side
No. 4 Ballast Pump	Pump Room inboard side
No. 6 Ballast Pump	Propulsion Room

It is noted that all the ballast pumps are located in the after end of each pontoon.

3.2 Type

The ballast pumps are of the vertical deepwell type

3.3 Capacity

Capacity curves for the full working range of the pumps have not been made available, the manufacturers quoted figure is: for each pump,

2000 gallons/minute at 170 ft TDH

(546 m^3/hour at 52 m TDH)

3.4 Operation

3.4.1 Ballasting

a) Ballasting can be carried out separately for each pontoon by pumping up the ballast tanks by using any combination or all of the ballast pumps.

b) Ballasting can also be carried out by flooding. This is achieved by opening tne remote operated butterfly valves connecting the ballast suction main to the ballast main and the sea chest. Each tank can then be flooded directly from the sea.

It is considered that there may be less control over ballasting whilst flooding than there would be when pumping. The ballasting rate can be controlled by the number of pumps employed at any time. Control over the rate of flooding is via the remote operated butterfly valve at the ballast main. This valve can only be placed in the open or closed position.

3.4.2 Deballasting

Deballasting is carried out by pumping out the ballast tanks via the ballast pumps. For emergency use, the ballast can be pumped using the drill water pumps.

3.4.3 Tanks

To maintain control over ballasting, one tank only should be dealt with at any time in each pontoon. With more then one ballast tank valve open in the same pontoon at any time, the following problems may be encountered.

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a) uneven ballasting or deballasting between the open tanks.

b) cross - flooding may occur between the ballast tanks.

3.5 Priming of Ballast Pumps

From the information available, there does not appear to be any independant method of priming the ballast pumps. Information on the self-priming capability of the ballast pumps from the "dry" condition has not been made available. From the information available, the methods of priming the ballast pumps that could be employed are:

a) Priming the ballast discharge main and the pump from the S.W. tank located at the cellar deck. Plans indicate, however, that each ballast pump is fitted with a non-return valve on the pump discharge.

The non-return valve will prevent each ballast pump "motoring" under the pumping action of other pumps that are running, but it will prevent priming of the pumps by filling the pump casings from the S.W. tank. This method of priming therefore would have limited success.

b) Priming the ballast pumps by taking a suction from a tank with a positive head relative to the pump. This method will be effective, if supervised correctly and will have little effect on the overall ballast condition in the pontoon provided once the pump has primed, it is switched to the tank requiring deballasting. A full tank used for priming may contribute a "free surface effect" to the stability after priming has been performed.

c) Priming the ballast pumps by opening the sea, suction valve, closing it again after priming is completed. The disadvantage of this method of priming is that the ballast system is usually set up for pumping out ballast when the pump may require priming. In this condition, opening the sea-suction valve will create a positive head in the ballast suction main which will effectively prime the ballast pump but it will also create a positive head in the ballast main which will cause the tank opened for pumping out, to fill. From a preliminary study, it may be possible for a positive head to exist in the ballast main in this condition even with all three ballast pumps running, fully primed and discharging overboard.

4. Ballast System Operation Failure

4.1 Sea Inlet Valve

If the sea inlet valve remained in the open position, the situation as described above in 3.5 (c) could arise causing the ballast tank open to the ballast system to fill and not empty as required.

4.1.1 For the sea inlet valve to be in the open position in error, some possible causes may be as follows:-

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a) A control system fault causing the valve to open or remain open.

b) An operator error, opening the valve by mistake, or leaving the valve open in error.

c) Mechanical failure of the valve causing it to remain in the open position, irrespective of the control system command.

d) Debris trapped inside the valve causing incorrect seating of the valve when attempting to move to the closed position.

e) Use of the sea valve to prime the ballast pumps, then allowing the valve to remain in the open position as described in 3.5. (c) above.

4.2 Ballast Tank Valves

If any two or more ballast tank valves are left in the open position at any time, the ballast tanks would be in direct communication via the common ballast main. As a consequence, the ballast in the tanks may cross-flood. If the two tanks involved were a forward ballast tank and an aft ballast tank then ballast may possibly level out by running from aft to the forward position, depending upon vessel trim and the contents of the tanks. The resultant increase in trim by the head caused by the shift in ballast would further increase the flow forward until either the aft tank emptied, the forward tank filled, or the two tanks levelled out.

Possible causes for this situation to occur to the ballast tank valves may be any or a combination of the reasons given in 4.1.1(a), (b), (c) and (d).

4.2.1 It is noted from the tank valve arrangements and tank positions of either the Drill Water tank Nos 5 and 13 or the Fuel oil tank Nos 6 and 12, that a levelling effect could take place in the manner indicated above for any two ballast tank valves being in the open or part open position.

4.2.2 There are no connections shown between Ballast/Bilge/Fuel Oil that could adversely affect trim or list. Therefore, incorrect operation or damage to the system will not cause any cross-connection between these various fluid systems.

4.2.3 Incorrect operation of the cross-over valves between the ballast and drill water systems coupled with incorrect operation of the drill water tank valves could cause cross-flooding with the ballast system or flooding of the drill water tanks from the sea.

4.3 Pumps

Although not apparent from the pump specifications, it is assumed that the ballast pumps are of a type capable of developing a 26ft suction head in the ballast suction main. This assumption is based upon the following assumptions due to lack of sufficient data:

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a) The pumps, when primed, are capable of maintaining a suction head.

b) The pumps are well maintained and in good working order.

c) The pumps are operated correctly.

d) The ballast system pipework is in a well maintained condition and does not leak at any point.

e) The valves associated with the ballast system pipework are in a well maintained condition and do not leak when in the closed position.

From the above assumptions, calculations carried out gave the following angles of trim at which it may not be possible to pump out any ballast from the given ballast tanks using any of the ballast pumps.

Ballast Tank Number	Minimum Distance of Tank Suction from the pump (m)	Angle of Trim to give loss of Suction (degrees) by the head)
1	88.345	8.6
2 + 3	75.217	10.1
4	63.635	12.0
7	51.443	14.9
8 + 9	40.775	18.9

5. Summary

On the basis of the data received, the ballast system was considered to be generally in accordance with the Society's Rules, except as indicated. The system could however, have been improved by the relocation of one of the ballast pumps to an accessible position in a pump room at the forward end of each pontoon with a direct means of communication to the control room for use in an emergency.

The remaining systems examined on the plans submitted were generally in order, their arrangement being such as would not significantly affect the trim of the vessel under fault conditions, except as already indicated in other sections of this report.

APPENDIX A

Plans examined

Ballast Pump Specifications and Details	Exhibit 30
Piping Diagram, Air, Sounding and Overflow System	G-3161-7 Rev.A
Air Pipe Head 30A	P-2027 Rev.B
Results of Sea Trial (Ballasting and Deballasting Test)	G-1014A

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Results of Sea Trial (Mooring and Cruising Test)	G-10148
Piping Diagram, Compressed Air System	G-3136-9 Rev.B
General Piping Plan, Keel Cooler(s)	P-4104 Rev.D
General Piping Plan, PC-1 lower part	P-4106 Rev.C
General Piping Plan, PC-2 lower part	P-4107 Rev.B
General Piping Plan, PC-3 lower part	P-4108 Rev.D
General Piping Plan, PC-4 lower part	P-4109 Rev.A
General Piping Plan, SC-1 upper part	P-4111 Rev.A
General Piping Plan, SC-2 upper part	P-4113 Rev.A
General Piping Plan, SC-3 upper part	P-4115 Rev.A
General Piping Plan, SC-4 upper part	P-4118 1/2 Rev.B
General Piping Plan, SC-4 upper part	P-4118 2/2 Rev -
Piping Diagram of Ballast, Drill Water and Bilge. Lower Hull System	G-3161-1-B
Piping Diagram of Drill Water System	G-3161-2-B
Piping Diagram of Salt Water Service System	G-3161-3-B
Piping Diagram of Fuel Oil Filling, Transfer and Service System	G-3136-4-A
Piping Diagram of Control Air System	G-3161-12-A
Piping Diagram of Tank-Level Indicating System	G-3161-15-A
Machinery Arrangement, Lower Hull Pump Room	P-0401
Arrangement of P-tanks in column	P-0402-A
Machinery Arrangement at Ballast Control Room	P-0403-A
General Piping Plan in Lower Hull Tanks	P-4101-A
General Piping Plan in Lower Hull Pump Room	P-4103-B
General Piping Plan Lower Hull Pump Room Control and Gage Piping	P-4116-B
Sliding Door Remote Operating System	W-2934

'OCEAN RANGER' INVESTIGATION

PART IB

REPORT ON CONTROL ENGINEERING ASPECTS OF THE BALLAST SYSTEM

"OCEAN RANGER" INVESTIGATION

Report on Control Engineering aspects of the Ballast Control System

1. INTRODUCTION

The plans listed in Appendix 1 have been appraised from Control Engineering aspects in respect of good engineering practice and accepted principles among the criteria for which we include the Society's Rules for the Classification of Ships.

In the course of our appraisal consideration has been given to:-

a) Ballast Pump Controls,

b) Ballast Valve Controls and associated power sources,

c) Ballast Tank Gauging arrangements as detailed below.

2. BALLAST PUMP CONTROLS

2.1 Operational Arrangements

The ballast pumps are arranged to be started and stopped by means of push button switches situated on the port and starboard ballast control mimic diagram panels.

2.1.1 It is concluded that the above push buttons are connected directly to their respective motor control centres.

2.2 Indication of Operational Status

Three means have been provided by which the operator is informed of the ballast pump operation.

2.2.1 Running and Stop Lamps on the mimic diagram panels indicate whether a pump motor contactor has operated.

2.2.2 Pump Discharge Pressure Indicators which show that pumps are rotating and primed.

2.2.3 Ammeters, indicating pump motor load, allowing the operator to deduce when liquid is being pumped.

2.3 Common Mode Failure

2.3.1 Plan No. NMA 298-3A shows a single power source for the pump running/stop lamps and for the pump discharge pressure indicators. These could therefore fail simultaneously as the result of a single fault.

2.3.2 Providing power were still available at the motor control centres the pumps would continue to run and the ammeters would still provide indication.

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2.4. Controls, Alarms and Safeguards.

2.4.1. The ballast pumps have simple on/off controls as stated in 2.1. above.

2.4.2. There would appear to be no alarms associated with the pump control circuits, nor indication of motor overload/trip at the ballast control console.

2.4.3. There are no system safeguards incorporated in the ballast control circuits at the ballast control console.

3. BALLAST VALVE CONTROLS AND ASSOCIATED POWER SOURCES.

3.1. Operational arrangements.

3.1.1. The ballast valves are operated by push button switches on the ballast control mimic diagram panels. When one of the "open" buttons is pressed, its normally-open contacts close and energise a relay which self-holds via the normally-closed contacts of the "close" button for that valve. A solenoid valve in the ballast control console is energised when the relay operates, and air is introduced to the ballast valves actuator to operate the valve to the open position. When the "close" button is pressed the ralay de-energises and the solenoid control valve moves to the vent position releasing air from the valve actuator which is of the spring close type, thus closing the ballast valve.

3.1.2. The latching characteristic of the relay circuit introduces a possible hazard. If the "open" push button contacts or the sustaining contacts of the relay are momentarily made by shock or vibration or are temporarily bridged by conducting particles or liquid the relay will hold in and cause the associated ballast valve to open.

3.2. Indication of Operational Status.

3.2.1. The port and starboard ballast systems each have two manually operated valves, one for the sea inlet, and the other for the overboard discharge. Lamps are provided on the ballast control mimic diagram panels to indicate when these valves are fully open or fully closed.

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3.2.2. The remotely controlled ballast valves are provided with similar indication lamps fitted within the "open" and "close" control push buttons. The circuits of these lamps include contacts of the selection relays in series with the micro switches on the ballast valves. The purpose of this arrangement is not apparent since it introduces a degree of separation between the indication and the function to be indicated. If a valve were to be opened by means of its local manual control the "close" lamp would be extinguished, but the "open" lamp would not be lit.

3.2.3. The air piping diagram for the solenoid valves shows that a pressure gauge is provided to indicate the air supply pressure for the ballast valve system.

3.3. Common Mode Failure.

3.3.1. Failure of either the electrical or air supply would cause all remotely operated valves to close. In the case of the electrical supply closure would be immediate. The storage capacity of the air system would delay closure in the case of air supply failure. Valve closure due to these causes would halt any ballasting operation in progress only until power could be restored or the necessary valves opened manually. These failure modes may be described as "fail safe".

3.3.2. Cutting off the electrical or air supply to the ballast control console could provide a useful means of effecting total shut down of the system in the event of control system malfunction.

3.4. Controls, Alarms and Safeguards.

3.4.1. Ballast valve control is effected by the push button circuits described in 3.1.1. above. There are no means of partially opening any of the remotely operated valves, or of indicating any position other than fully open or closed.

3.4.2. There would appear to be no alarms provided for the ballast valve control system. The Society's present ship rules require audible and visual alarms for the failure of power supplies to control systems. In this case both the electrical and air supplies would require failure alarms. Failure of a valve to move to the selected position has the result that both the "open" and "close" lamps for that valve remain unlit after the normal travel time of the valve. Since a lamp test facility is provided, and the operator is in attendance at the console, it is not considered necessary that this failure should raise an alarm.

3.4.3. Apart from fuses and relief valves to protect the electrical and air systems, there would appear to be no safeguards provided in the ballast control system.

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3.4.4 Selection of the ballast valves to be opened is the responsibility of the operator using the system as designed. While such a system would be acceptable, it could be improved by the incorporation of alarms or interlocks to inhibit the selection of hazardous combinations of valve opening.

4. BALLAST TANK GAUGING

4.1 Operational Arrangements

Each ballast tank is provided with an individual depth of contents gauge of the manometer type. These are mounted on panels in the ballast control room but not adjacent to the ballast control console.

4.2 Indication of Operational Status

Each gauge is provided with a flow meter to indicate that the air is flowing through the system and therefore the gauge reading is valid.

4.3 Common Mode Failure

The air supply to the tank gauging system is common with that to the ballast valve control console.
Failure of the air supply to the gauges would render their readings invalid and this should be apparent to the operator because all the flow meters would show no flow. Since the ballast valves would also spring shut under these circumstances, the tank contents should remain unchanged until the air supply can be restored and the system becomes operational again.

4.4 Controls, Alarms and Safeguards

4.4.1 The only relevant control in the ballast tank gauging system is the one by which the operator is enabled to purge the system periodically. Its frequency of use is a matter of operational procedure.

4.4.2 There are no alarms associated with the gauging system. If the air supply to the ballast valve control console were to be provided with a failure alarm in accordance with current requirements, this would also cater for failure of the supply to the gauges.

4.4.3 There are no safeguards built into the gauging system. Reliance is placed on the operating procedures to ensure that purging of the system is carried out at the requisite intervals, and that the flow indicators are checked before any readings are taken.

/Cont'd ...

5. SUMMARY.

On the basis of the ballast system data received, the pump control, valve control and tank gauging systems are considered to be in accordance with the Society's ship rules prevailing at the date of build. It is suggested, however, that the system could be improved by the provision of electrical and air supply failure alarms, and by inhibiting the selection of hazardous combinations of valve opening.

APPENDIX 1

Piping diagram of control air system	G-3161-12
Piping diagram of the tank level indicator system	G-3161-15
Ballast control console plan No. P-3113 including:-	
Ballast control console	NMA-298
Mimic diagram of control face (Starboard hull)	NMA 298-1-1
Mimic diagram of control face (port hull)	NMA 298-1-2
Arrangement of Press. gauge & alarm lamp, ammeter	NMA 298-1-3B
Air piping diagram for solenoid valves	No. not shown
Elementary diagram of solenoid valves operator switch and valve open-close indicator lamp (stbd hull)	NMA 298-3-4B
Elementary diagram of solenoid valve operator switch and valve open-close indicator lamp (port hull)	NMA 298-3-5B
Elementary diagram of open and close indicated lamp for manual valve	NMA 298-3-6
Power line circuits for ballast control console	NMA 298-3A
Remote control push button and lamp circuits for B.W.P. & D.W.P., F.O.T.P.	NMA 298-3-2
Elementary diagram of alarming device	NMA 298-3-8B

'OCEAN RANGER' INVESTIGATION
PART IC
REPORT ON ELECTRICAL ASPECTS OF THE BALLAST SYSTEM

"OCEAN RANGER" INVESTIGATION

Report on Electrical aspects of The Ballast System.

1. The electrical aspects of the plans submitted and listed in Appendix A have been considered using good engineering practice and accepted principles which include the Society's Rules for Mobile Offshore Units current at the time of building, and the following comments are made.

2. Analysis of flooding or other casualty on electrical system.

   2.1. The effects of flooding or other casualty on the electrical system has been considered using a single fault concept and the details are given below.

FAILURE CONSIDERED	POSSIBLE CAUSE	BALLAST PUMPS AVAILABLE*
Loss of main power	Fire in machinery space. Flooding in machinery space. Switchgear busbar fault.	5 & 6 fed from emergency switchboard.
Loss of either main generator No. 1 or No. 2	Prime mover failure Generature failure Electrical fault	All ballast pumps.
Loss of emergency power	Fire in machinery space. Flooding in machinery space. Emergency switchboard fault.	1, 2, 3 & 4.
Loss of emergency generator	Prime mover failure Generator failure Generator incomer fault.	All ballast pumps.
Loss of MCC4 or MCC5	MCC busbar fault Feeder cable fault	1, 3, 5 & 6 or 2, 4, 5 & 6
Loss of stbd. or port pump room	Fire in pump room Ø Flooding in pump room Ø	1, 3 & 5 or 2, 4 & 6
Loss of ballast control console	Fire in ballast control room	Not known see 2.2.4.
Damage to cable run	Fire in any one compartment	Not known see 2.2.5.

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* Assumed that generator loadings are such that ballast pumps are available as noted.

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Ø Assumed that watertight bulkhead separates the main ballast pumps from the ballast pump motor and starter fed from the emergency switchboard.

2.2. It has not been possible to establish the following, due to lack of information:-

2.2.1 That the circuit breakers and fuses in the main and emergency switchboards and MCC's 4 & 5 are suitable for the prospective fault currents.

2.2.2. That satisfactory discrimination exists between protective devices i.e., fuses and circuit breakers in the supply systems to MCC's 4 & 5.

2.2.3. That loading or preference tripping arrangements are such as to ensure continuation of power supply to the running pumps under system overload conditions.

2.2.4. That a common mode failure in the ballast pump control circuits would not prevent all ballast pumps from working e.g., that a fire in the ballast control console would not cause both the remote and local starting circuits of all pumps to be open circuited.

2.2.5. That power and control cables for the ballast pumps are separated such that a fire in any one compartment could not put all of the pumps in one or both pump rooms out of action.

2.2.6. That the arrangements for starting the standby main generator and emergency generator are such as to ensure security of electrical supplies.

3. Failure modes are considered under sections 2.1 and 2.2. Subject to satisfactory arrangements being provided to meet section 2.2, it is considered from the plans examined that on a single fault basis, the conditions would not constitute a hazard to the unit.

APPENDIX A

PLANS EXAMINED.

W-3301 Rev. 6
02 Rev. 6
03 Rev. 6
04 Rev. 4
05
06 Rev. 6
11 Rev. 6
12 Rev. 6
13 Rev. 6

W-3314 Rev. 6
15 Rev. 6
16 Rev. 6
W-3701 Rev. 5
02 Rev. 6
03 Rev. 4
05 Rev. 6

'OCEAN RANGER' INVESTIGATION

PART II

STABILITY

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'OCEAN RANGER' INVESTIGATION
STABILITY

THE RESULTS OF THE SOCIETY'S INVESTIGATION CONCERNING THE STABILITY OF 'OCEAN RANGER' ARE CONTAINED IN THIS REPORT.

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3. Information and Data in the 'Ocean Ranger' Booklet of Operating Conditions

4. Displacement and Centre of Gravity of 'Ocean Ranger' prior to the Accident

5. Moorings

6. General Aspects of the Stability of 'Ocean Ranger'

7. Survival Condition

8. Sequence of Events

9. Contents of Lower Hull Tanks Before and After Capsize

10. Possible Transfer of Ballast

11. Sundry Considerations

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Figure 7 Results of Acoustic Soundings of Air Pockets in Tanks

Notes to Tables 6A and 6B (Calculations Concerning Tank Contents)

Table 6A (Calculations Concerning Tank Contents)

Table 6B (Calculations Concerning Tank Contents)

Figure 8 After Flooding from Tank PT10 to PT4

Figure 9 After Flooding from Tank PT10 to PT1

'OCEAN RANGER' INVESTIGATION

Report on Stability

1. Introduction

1.1 An investigation of the stability of 'Ocean Ranger' has been made with the following main objectives:

(a) To assess whether the information and data in the Booklet of Operating Conditions of 'Ocean Ranger' is correct in accordance with applicable Rules and Regulations concerning stability.

(b) To assess whether the loading of the rig immediately prior to the accident complied with the applicable stability Rules and Regulations.

(c) To assess, as far as possible, the probable cause of the accident.

1.2 The stability of 'Ocean Ranger' was subject to requirements in the 1973 edition of the Rules for Building and Classing Offshore Mobile Drilling Units of American Bureau of Shipping. Additionally, as a result of a change of the country of registration of 'Ocean Ranger' from Panama to the United States the stability would have been also subject to the regulations of the United States Coast Guard.

1.3 This investigation is, of necessity, based on the Society's understanding of the requirements of the stability rules of A.B.S. and of the U.S.C.G. respectively. From the U.S. Federal Register Volume 47 No. 233 no important difference is seen between the U.S.C.G. stability requirements and those of A.B.S.

1.4 This investigation has been made on the basis of drawings and documents listed in Annex 1.

2. Hull Definition of 'Ocean Ranger'

2.1 From the relevant drawings in Annex 1 the hull geometry of 'Ocean Ranger' has been defined as input data for the Society's program LR 428 which has been used for various stability computations needed for the tasks 1.1 (a) and 1.1 (c) above. The hull definition corresponds to 'full' displacement, i.e. input data defines the outer surface of the shell plating of the rig. The appendages, comprising boat bumpers, anchor racks, Kort nozzles and keel coolers, are included in the hull definition. For computations concerning the allowable vertical centre of gravity of the rig the upper hull (excluding the moonpool) is defined as buoyant. For computations which assume flooding to the upper hull a permeability of 96% is applied to the upper hull buoyancy.

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2.2 Input data for the computations and output data (except where otherwise labelled) is in metric units (metres and metric tons). Imperial units (long tons and feet) are used throughout this report.

2.3 The co-ordinate axis system used for the hull definition of the rig is shown on Figure 1 and the two angles and one dimension used by the program to identify any floating position of the rig are shown on Figure 2.

3. Information and Data in the 'Ocean Ranger' Booklet of Operating Conditions

3.1 Lightweight and Centre of Gravity

Section B of the Booklet 'Verification of Lightweight and Centre of Gravity' has been examined and no objection is found to the lightweight and centre of gravity.

3.2 Tank Calibrations

The data for lower hull tanks given in Section G of the Booklet has been checked and satisfactory agreement obtained.

3.3 Hydrostatics

Section H of the Booklet 'Hydrostatic Properties' has been compared with hydrostatic data computed from the Society's hull definition, paragraph 2 above. Some small differences exist between the two sets of hydrostatic data. We have not been able to identify the reason for these small differences or to form an opinion as to which hydrostatic data is the more accurate. The Society's data is included at Table 1.

3.4 Allowable VCG

Pages C6, C7 and F of the Booklet describe and define the allowable vertical centre of gravity curves for 'Ocean Ranger'.

It is a characteristic of the ABS and similar intact and damage stability criteria that at low or intermediate drafts a semi-submersible unit may satisfy the stability criteria although the metacentric height of the unit, 'GM' may be negligibly small. For 'Ocean Ranger' a minimum GM of 1.5 ft. has been added, as an Owner's requirement, in the allowable VCG curves.

From page L2 (rev. 1) of the Booklet it is noted that consideration has been given to the possibility of damage to lower hull compartments not only when the unit is at transit draft but also when it is at operating draft. This is also, we believe, in excess of the mandatory damage stability requirements of ABS/USCG.

Computations have been made by the Society to check the allowable VCG curves in way of the draft range 58 ft. to 80 ft.

For the intact stability computations the co-ordinates of the potential downflooding points are as listed on Table 2. All of these points correspond to the outboard sides of the chain pipes and cable trunks which extend from the upper deck to the chain lockers in corner columns. For damage stability computations it is not permissible for the end of any air pipe

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(tank vent) to be submerged after damage. Accordingly the positions of the ends of air pipes under the lower deck were estimated from drawing no. 3161.7 and these positions were included as additional potential downflooding points. (None of these were found to be more critical than the chain locker downflooding points).

We have assumed that there are no other openings which would form downflooding points more critical than those mentioned above. As 'Ocean Ranger' had a Load Line Certificate it is possible that Load Line survey reports, giving particulars of all openings to the upper hull, may exist.

Satisfactory agreement was obtained with Section F of the Booklet in regard to damage stability. The most critical damage case at 80 ft. draft was found to be damage to PC2 and the corresponding maximum VCG to satisfy the damage stability criteria was 66.7 ft.

Initially our computations did not give satisfactory agreement with page F of the Booklet in regard to the VCG for compliance with the intact stability criteria for assumed wind speeds of 70 knots and 100 knots. It was concluded some difference might exist between the wind moments used in computing the allowable VCG curves in the Booklet and the wind moments given by the Society's program.

The calculation method for wind moments contained in ABS Rules or USCG Regulations is rather brief, leaving some aspects of the calculations undefined. The undefined aspects could, equally reasonably, be interpreted in slightly different ways; slightly different end results for wind moments would occur. A re-appraisal was made of our method of calculating wind moments and all non-mandatory features which could possibly lead to higher wind moments than would otherwise be obtained were eliminated.

The intact stability computations were repeated with the modified wind moment data and a close, but not complete, agreement was obtained with the curves of page F of the Booklet. The results obtained at 80 ft. draft are:

Maximum VCG, operating	64.5 ft.
Maximum VCG, survival	57.5 ft.

The following items are appended:

Table 3	Intact stability, computation of allowable VCG for 80 ft. draft and 70 knot wind.
Figure 3	Plotting of maximum VCG versus heeling direction.
Figure 4	Plotting of maximum VCG versus draft.

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3.5 Instructions for Calculating Stability and for Acceptable Loading Under Normal Conditions

Section C of the Booklet is exceptionally clear and comprehensive.

The recommendation (b) on page C13 as amplified on page C15 would tend to minimise any spare capacity in the aft ballast tanks numbers 14, 15, 16 and therefore to minimise the capacity of the rig to counterflood in the event of damage and flooding to a compartment in the forward part of the rig. (However, the ballast distribution prior to the accident appears not to have been influenced by the recommendation (b) on page C13).

4. Displacement and Centre of Gravity of 'Ocean Ranger' Prior to the Accident

4.1 The information about the loading of the rig prior to the accident comprises copies of the stability reports for 25th January, 1st February and 9th February, 1982, copies of the control room log for 10th and 11th February, 1982 and copies of the morning reports from the rig for 9th to 14th February, 1982 inclusive. These documents have been considered to assess the probable VCG of the rig on 14th February, 1982 prior to the accident.

4.2 All of the documents 4.1 above state 80 ft. for the draft of the rig. On the three stability reports the totals for calculated displacement are consistent with the draft being maintained (within some small tolerance) at 80 ft.

4.3 Table 4 (in this report) gives a summary of data extracted or derived from the documents 4.1 above. The copies received of the control room logs for 10th and 11th February each comprise two sheets, one being the left hand part of the log page and the other the right hand part of the log page. The left hand parts show the date (10th or 11th February, 1982). From the right hand sheet which is thought to be from the log for 10th February, 1982 the tank soundings indicate about 244 LT of drill water and about 34 LT of fuel oil were taken on board from a supply boat between 0800 and 1400 hours.

4.4 Each morning report includes a figure for fuel oil, a figure for potable water and a figure for drill water. These figures (after conversion from barrels to LT) are shown on Table 4. The figures for fuel oil from the morning reports seem slightly higher than would be expected from the stability reports and the control room log.

4.5 Table 4 shows the information obtained from the stability reports and morning reports about the VCG of the rig after correction for transverse free surface ('VCGT') and after correction for longitudinal free surface ('VCGL').

4.6 The tanks of 'Ocean Ranger' which account for the major part of the free surface correction have a longitudinal free surface which is greater than their transverse free surface. The figures for VCGT and VCGL from the stability reports show, as would be expected, that VCGL is greater than VCGT, and they show that the difference is typically about 0.7 ft.

4.7 The last column of Table 4 shows, both for the stability reports and the morning reports, the value of (VCGL) - (VCGT). It is seen that for some of the morning reports, i.e. 9th, 12th, 13th and 14th February, the value is somewhat different to the value of about 0.7 ft. shown by the stability reports. We are inclined to believe that the VCG data given by the morning reports may be less accurate than the data given by stability reports.

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4.8 The weight of deck load shown by the morning report for 14th February is practically the same as the deck load shown by both the morning report and the stability report for 9th February. For the reason mentioned under 4.7 above it is thought that the VCG information from the stability report of 9th February may be a better indication of the VCG on 14th February than the morning report for 14th February.

Further information was received in a telex from the Petroleum Directorate dated 11th January, 1983, which refers to a working copy of the 14th February, 1982 stability report obtained from the diving survey and shows the contents of each lower hull tank on 14th February, 1982.

Table 5 shows the estimate of the weight and centre of gravity of the rig based on the following assumptions:

(a) No additions to the deck load (i.e. from a supply boat) occurred subsequent to the 9th February stability report.

(b) The information from the 14th February, 1982 stability report, mentioned above, can be used to update the 9th February, 1982 stability report in regard to lower hull tanks.

(c) At the time of the accident the drill string was hung off in the well; we assume the weight of the drill string to be the same as the load on the set back on 9th February and therefore remove this load from the calculated displacement.

A small error was found in the arithmetic of the 9th February stability report and this has been corrected in Table 5.

The resulting displacement and centre of gravity are as follows:

displacement	38748 LT
VCGT	62.63 ft
VCGL	63.64 ft

The VCG values are satisfactory in relation to the maximum allowable VCG for operating conditions. The VCG values are higher than the allowable VCG for survival conditions and the rig would require to deballast to a lesser draft for the survival condition.

4.9 The lightweight and lightweight VCG of a semi-submersible rig are liable to increase subsequent to the inclining test carried out on completion by the builders. Such increases tend to occur due to additions and alterations to equipment fitted to the rig. It is therefore advisable that barge masters keep a

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record of the weight and centre of gravity of every alteration to lightweight which occurs subsequent to an inclining test. Accordingly, the up-to-date total for lightweight alterations can be included in stability reports.

The stability reports from 'Ocean Ranger' include (on Table 6 of the reports) a lightweight correction of 200 LT with VCG 145.8 ft, a zero LCG and a zero TCG. It is not evident whether this correction was obtained from a record of known lightweight additions or whether it is a figure which has been deduced by comparing the draft corresponding to the calculated displacement with the observed draft, i.e. observations during calm sea conditions of the draft marks on the columns.

4.10 It is important that the contents of the lower hull tanks of a semi-submersible rig are not overestimated in stability reports. Any such overestimate could mask the presence of some unrecorded weight at the deck and cause the calculated VCG of the rig to be too low.

Page K2 of the Booklet of Operating Conditions contains the instruction: 'Sound tanks weekly and check against gauge readings. Check to be recorded and condition entered in log'. In common with most other semi-submersible units, on 'Ocean Ranger' the sounding pipes to lower hull tanks are, of necessity, located at the ends rather than at the centres of the tanks. Except under very calm sea conditions manual soundings would be prone to overestimate liquid levels in partly filled tanks due to motions of the liquid surfaces.

The figures for lower hull tank contents on the stability reports will almost certainly have been obtained from the readings of the tank sounding gauges in the control room. The validity of the available information about the VCG of the rig is particularly dependent on an assumption that the tank sounding installation was reliable and accurate. We have no reason to suppose the sounding installation on 'Ocean Ranger' was not reliable and accurate.

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5. **Moorings**

5.1 The length of each anchor wire is understood to be 5600 ft. and the length of each anchor chain is understood to be 1650 ft.

According to the sketch 'Odeco Ocean Ranger J-34 Anchor Pattern' the total length of moorings outboard of the fairleads was 56783 ft. Deducting the length of 12 chains each 1650 ft. long, leaves 36983 ft of wire outboard of the fairleads. The wire on board the rig inboard of the fairleads would therefore be:

(12 x 5600) - 36983 = 30217 ft.

Referring to page C21 of the Operating Booklet, corresponding to 30217 ft. inboard of the fairleads the weight and VCG for stability calculations would be as follows:

	TOTAL FT.	TOTAL L.T.	VCG FT.	V MOMENT FT. x L.T.
Fairleads to winches	12 x 248	30.42	119.29	3629
Winch reels	27241	278.49	158.27	44077
	30217	308.91	154.43	47706

The stability reports for 25th January, 1st February and 9th February, 1982 show 192 LT of wire at 158.3 ft. VCG. The 30.4 LT for wires between fairleads and winches is not shown separately; it must be assumed this has been included in the stated 192 LT of wire.

There is therefore a discrepancy of 117 LT (i.e. 11436 feet of wire) between the stability reports and the wire expected to be on board according to the sketch of the anchor pattern.

Possible explanations for the discrepancy might be one or more of the following:

(a) At some time after the sketch of the anchor pattern was made some anchors were re-laid further from the rig.

(b) Some anchor wires might have been shortened from their original length of 5600 ft. in order to scrap a part of the wire which had become damaged.

(c) Some anchor lines might have had less than 1650 ft of chain. (The remaining possibilities, namely that the length of line out was wrongly assessed when the sketch of the J-34 anchor pattern was made, or that the wire on board was wrongly assessed in the stability reports seem very unlikely).

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5.2 Mooring Restraint

An assessment has been made of the restraint to inclination of the rig that might have been provided by the mooring system. The following assumptions were made:

(a) The sketch 'Odeco Ocean Ranger J-34 Anchor Pattern' assumed correct in regard to line length.

(b) The water depth in way of the touchdown areas of moorings assumed the same as water depth at the rig.

(c) Slackening of leeward moorings (to reduce tensions in windward moorings) was assumed not to have taken place.

The restraint from the mooring system was found to be closely similar for different axes of inclination. The restraint to a couple (e.g. a moment caused by a transfer of ballast from one tank to another) and the reduction of the VCG of the rig to simulate the restraint are as follows:

INCLINATION (DEG)	MOMENT (FT-LT)	EQUIVALENT REDUCTION OF VCG (FT)
10	22000	3.2
20	53000	4.0
30	123000	6.3
40	245000	9.8

5.3 Mooring Reaction to Horizontal Force

An assessment has been made to determine the 'neutral height' at which a steady horizontal force applied to the upright rig will cause no inclination of the rig.

With the assumptions (a), (b) and (c) of 5.2 above and considering the direction of the applied horizontal forces to be about 20° forward of the Port beam (i.e. as Load Case 1 of the mooring study in this report) the neutral height of the mooring system is at a level approximately 15.7 ft. above the bottom of the fairlead sheaves, i.e. about 108.7 ft. above the base line of the rig.

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6. General Aspects of the Stability of 'Ocean Ranger'

6.1 The computed righting and wind heeling arm curves of 'Ocean Ranger', for 80 ft. draft and with an assumed VCG of 63 ft. are shown on Figure 5. The curves disregard the effect of the mooring system, i.e. they correspond to the assumptions which apply in stability calculations to determine the allowable VCG of the rig. (Note: As the curves on Figure 5 are for longitudinal, transverse and diagonal 'heeling' directions, 'heel' should be understood to mean 'inclination from upright').

6.2 The curves on Figure 5 imply that in the absence of any ballast adjustment the rig would take up a mean inclination 7° to 9° under a 70 knot wind or 15° to 17° under a 100 knot wind. However, such conclusions are not valid if the mooring system is taken into account.

6.3 In the following calculation an estimate is made of the ballast adjustments needed to maintain an upright mean position under the reported 72 knot wind at 0000 hours GMT on 15th February, 1982, and an estimate is made of the inclination of the rig if no ballast adjustments are made.

The following assumptions are made and the end result should be regarded as a rough approximation.

(a) Wind effect may be represented by a steady horizontal force at a constant height.

(b) Wave drift effect may be represented by a steady horizontal force having the same direction as the wind force and acting at the position of the calm sea centre of underwater projected area corresponding to 80 ft. draft.

(c) Current effect is ignored (as it is not directly related to the wind and wave effect).

The reported wind speed was 72 knots at an anemometer 79m (259.2 ft.) above sea level. Wind direction 20° forward of the Port beam.

(For the calculations the wind force and the height of the centre of wind force are obtained from the wind moment subroutine of the Society's program LR 428.At the level of the anemometer the ABS height coefficient, $\underline{C_H}$, is 1.43. Accordingly an input surface wind speed of $72/(\sqrt{1.43})$, i.e. 61.05 knots is assumed in order to obtain 72 knots at the level of the anemometer).

Wind force = 162 LT
Centre of wind force, above base = 159.9 ft
Neutral height of mooring system, above base = 108.7 ft
Vertical level arm = 51.2 ft
Wind moment = 8294 ft x LT

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Wave drift force = 43.8 LT
Centre of underwater projected area, above base = 34.1 ft
Neutral height of mooring system, above base = 108.7 ft
Vertical lever arm = - 74.6 ft
Wave drift moment = -3267 ft x LT

Net heeling moment = 5027 ft x LT

Transverse moment = 5027 sin 70° = 4724 ft x LT
Longitudinal moment = 5027 cos 70° = 1719 ft x LT

(Required ballast moments 4724 ft x LT Starboard to Port and 1719 ft x LT aft to forward).

Assuming the No. 4 and No. 14 ballast tanks are used the required ballast changes would be as follows:

Tank	Ballast change (LT)
PT 4	+ 18.2
PT14	+ 9.2
ST 4	- 9.2
ST14	- 18.2

Without the ballast adjustments indicated above the mean angles of heel and trim due to the estimated wind and wave drift moments would be very small.

(In the following calculation the probable VCG figures mentioned under paragraph 4.8 above are assumed. As mentioned under paragraph 3.3 above there are small differences between the Society's hydrostatic data and the hydrostatic data in the Booklet of Operating Conditions; the Society's data is used here).

Transverse GM = KMT - VCGT
= 68.24 - 62.63
= 5.61 ft

Longitudinal GM = KML - VCGL
= 66.61 - 63.34
= 3.27 ft

To represent the restraint due to the mooring system the calculated GM figures require to be increased by about 3 ft.

Angle of heel = arcsin 4724/(38818 x 8.61) = 0.8°
Angle of trim = arcsin 1718/(38818 x 6.27) = 0.4°

6.4 The figures for ballast adjustments or for angles of inclination in the absence of any ballast adjustment as calculated under 6.3 above must be regarded as strictly approximate, due to simplifications inherent in the assumptions

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6.3 (a) and (b). However, it is concluded that due to the unusually high position of the mooring fairleads inclination of the rig due to wind effect would be considerably smaller than would be the case had the mooring fairleads been fitted at the more usual location, i.e. at about the level of the horizontal bracings.

So far as wind effect is concerned a high position of the mooring fairleads is clearly beneficial. What is less clear is whether any adverse effect is associated with a high position of the mooring fairleads.. (Model tests to study the motions of the moored rig under the reported wave conditions would be necessary to clarify this aspect).

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7. Survival Condition

7.1 Operating manuals of semi-submersible units usually contain some guidance as to the circumstances under which it would be prudent for operating personnel to de-ballast the unit from operating to survival draft.

Operating manuals of different units differ in the parameters used for this; some use the maintenance of an air gap (i.e. wave clearance under the deck) as the parameter, others recommend that de-ballasting to the survival draft should take place if roll/pitch or heave exceed stated figures, others recommend that de-ballasting to survival draft should take place if the wind speed exceeds (or alternatively if the wind speed is expected to exceed) a stated figure, usually 70 knots.

Some semi-submersible units are able to comply, at their operating draft, with the intact stability criteria applicable to the 'survival' (also called 'safety') condition (i.e. an assumed wind speed of 100 knots). Others, probably a majority of semi-submersible drilling units (including 'Ocean Ranger') comply, at their operating draft, with the intact stability criteria applicable to operating modes, and require to de-ballast to a lesser draft (and/or reduce deck load) in order to satisfy the intact stability criteria applicable to the survival condition.

For units of the latter type operating manuals usually adopt wind speed in excess of 70 knots as the parameter, or as one of the parameters, which should be regarded as necessitating the change to the survival condition.

7.2 The 'Ocean Ranger' Booklet of Operating Conditions states at Page K1 'Under exceptionally severe storm conditions the barge should de-ballast to an appropriate draft to meet the requirement for Safety Condition (see C18 - C19).'

Chapter C of the Booklet also contains the following at page C9, 'In the event winds in excess of 70 knots are forecast the unit in this condition must be de-ballasted to about 58 feet draft in order to meet allowable KG for 100 knot wind (see page F and C6).'

7.3 The standard method of defining wind speeds at sea is on the basis of the one minute mean speed at a height 10 metres above sea level. Under ABS and USCG rules a 70 knot wind speed at this level would correspond to a wind speed of $70 \times \sqrt{1.43}$, i.e. 83.71 knots at the level of the anemometer fitted to 'Ocean Ranger'.

The available information about wind speeds at 'Ocean Ranger' on 14th/15th February, 1982 is:

(a) The Meteoroligical Factual Report, April 7th, 1982
(b) The C. Noll Report, 5th March, 1982

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From item (a) the maximum reported wind speed is 72 knots and maximum reported gusts are 88 knots.

Item (b) reports a message from 'Ocean Ranger' which includes 'Winds 90 to 105 knots av. 78 knots'.

It is our understanding that the average speeds, not the gust speeds, should be compared with the figure 83.71 knots at the level of the anemometer. Accordingly, it was not necessary for 'Ocean Ranger' to change to survival condition due to the wind speed.

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8. Sequence of Events

8.1 The report by C. Noll dated 5th March, 1982 has been used as the reference document regarding the sequence of events relating to the loss of the 'Ocean Ranger'.

8.2 The report of the second investigation into the loss of 'Ocean Ranger' conducted by Mobil Oil using the vessels 'Balder Cabot' and 'Polaris V' February 28th to March 3rd 1982, by Glenn R. Cobb has been used as a reference document concerning the location and orientation of the rig after the capsize.

8.3 From 8.1 above we envisage the most significant events were the following:

(a) At a time, probably shortly before 19.50 hours NST on 14th February, 1982, the glass of one of the portlights of the ballast control room broke; some water entered the ballast control room watting some of the panels of the ballast control desk. Some water accumulated on the floor of the ballast control room and was mopped up. Water contacted, and put out of use, the PA system. Electric shocks were felt from a panel in the ballast control room; the panel in question may have been the ballast control desk.

(b) A message from the rig at between 19.50 and 20.50 hours NST stated 'all valves here on the Port side are opening by themselves'. A message from the rig at 21.00 hours NST stated 'valves were opening and closing on their own'.

(c) Some of the messages from the rig at 20.45, 21.06, 21.30, 22.00, between 22.00 and 22.15 and at 23.35 hours NST mentioned the event (a) above and confirmed everything was satisfactory, and some were about other subjects and therefore did not refer to the event (a) above. At 22.00 hours there was possibly a mention of pumping out and maintaining trim.

(d) A Mayday was sent by 'Ocean Ranger' at 00.52 hours NST on 15th February, 1982. The final radio message from the rig was at 01.30 hours at which time personnel evacuated the rig by lifeboats.

(e) Messages from the rig describe listing of the rig as follows:

At 01.00 hours NST: 'Rig listing bow down 8 to 10 ft.'.

(It is assumed the above message may mean 'degrees' rather than 'feet'.)

At 01.05 hours NST: 'A list to Port and all countermeasures are ineffective'.

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At about 01.08 hours NST: ' ... severe list of 10 to 15 degrees ... listing severely 12 to 15 degrees to the Port side ...'

At 01.20 hours NST: 'Rig at 12 degree list'.

(f) Two vessels, 'Seaforth Highlander' and 'Boltentor' approached and sighted 'Ocean Ranger':

At 01.50 hours: 'Seaforth Highlander' directly downwind, approaching from downwind - aft. Port. Could not say the rig was listing, all lights were on ...'

At 02.35 hours: The 'Boltentor' arrived at the 'Ocean Ranger', saw two lights on (green light at centre and a small light). The rig looked square and derrick vertical, no sign of life, thought it was deballasted.

(At the time of the 'Seaforth Highlander' sighting of 'Ocean Ranger' the wind direction at the adjacent rig 'Sedco 706' was 260°. If the wind direction at 'Ocean Ranger' was similar, the down wind part of 'Ocean Ranger' would be Starboard aft rather than Port aft. If 'Seaforth Highlander' viewed 'Ocean Ranger' from Starboard aft rather than Port aft a list by the Port bow might not have been apparent to 'Seaforth Highlander'. It does not seem possible for the derrick of 'Ocean Ranger' to have been vertical at 02.35 hours as reported by 'Boltentor').

(g) Radar contact with 'Ocean Ranger' was lost at 03.38 hours and a helicopter at the site of 'Ocean Ranger' at 04.47 hours did not see the rig.

8.4 From the underwater survey report 8.2 above it is evident that to attain its present position on the sea bed the rig must have capsized in an approximately bow-down direction. The mooring lines 1, 2, 4 and 5 are reported broken. It is envisaged that mooring line 3 must also be broken. It is also envisaged that the breakage of the mooring lines occurred at some stage of the capsize sequence as a result of the increased mass and increased resistance to wave forces at the stage of the capsize.

8.5 There seem to have been four phases to the accident.

The first phase would commence with the breakage of the portlight and extend to 23.35 hours when a routine weather report was transmitted from the rig at the routine time. Thus this phase lasted about 4 hours. During this time no message from the rig referred to any listing of the rig, but there may have been one message which referred to pumping out and maintaining trim.

The second phase lasted about 2 hours. During the first 77 minutes a severe list occurred and a Mayday message was sent. At the end of this phase the rig was evacuated.

During the third phase the rig was afloat and any list was not observed by 'Seaforth Highlander' at 01.50 hours or by 'Boltentor' at 02.35 hours. Thus it would seem this phase may have lasted at least one hour.

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During the final phase the rig capsized and sunk. This phase seems to have taken place in 1 to 2 hours.

9. Contents of Lower Hull Tanks Before and After Capsize

9.1 It is not known at what time on 14th February, 1982 the stability report mentioned under 4.8 above was made. However, it is assumed that it is the best available information about contents of the lower hull tanks at some time on 14th February before the breakage of the control room portlight. These tank contents are shown on Figure 6.

Figure 7 shows the results of acoustic soundings of the air pockets in tanks and compartments (as advised by the Petroleum Directorate's telex dated 28th July, 1982 and letter dated 19th August, 1982) and the estimated percentage filling (by liquid) of each tank and compartment, corresponding to the air soundings.

9.2 We have made a number of attempts to derive, from the acoustic soundings, some reconstruction of the probable contents of individual tanks at the start of the capsize. We have to advise that these attempts have been highly unsuccessful and have not yielded any information which is either conclusive, or even probable, about the contents of individual tanks before the accident. For general information the details of the investigation are summarised below.

9.3 The tanks at the fore end of each lower hull are reported to be damaged, i.e. tanks nos 1 and possible also nos 2 and 3. No damage has been reported to the other tanks of the lower hull. It is therefore concluded that each of the tanks numbered 4 to 16 has three possible routes whereby water or air could enter or leave the tank during, or subsequent to, the capsize:

i) The tank filling/suction pipe.
ii) The combined air and sounding pipe.
iii) A (small bore) pipe to the tank sounding installation.

In regard to (i) it would be expected all tank suction valves would be closed. The valve actuators are now subject to an external hydrostatic pressure of about 105 ft. of water. (We do not have detailed drawings of these actuators).

The possibility that some, or all of the suction valves are now open, or partly open, due to external pressure on the valve actuator or some other reason cannot be excluded.

In regard to (ii) the combined air and sounding pipes would have float-operated anti-flooding valves at their outer ends, which are located under the lower deck. The detailed drawings of these valves have not been seen, but they are possibly of similar design to those shown on drawing P-3002. During the capsize the floats in these valves would almost certainly move to the closed position due to external hydrostatic pressure. It is a common practice for air pipes to have a small hole

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(sometimes called a vacuum-breaker) inboard of the float valve, so that if the valve closes due to wave action at a time when liquid is being pumped from the tank the float is not retained in the closed position due to suction of air through the air pipe. It is not known whether 'Ocean Ranger' has this feature; if it does water would flow through the air pipe until any air pocket in the tank has compressed to the local hydrostatic pressure. At that stage the float would move from the closed position to the open position (unless it has been damaged by the high hydrostatic pressure). Depending on the size of the vacuum-breaker holes and of the air pocket a period of several weeks or months might be necessary before equilibrium was obtained.

The small bore pipes of the tank sounding system, item (iii) above, might possibly provide further routes for water to enter tanks following the capsize, though this is rather uncertain.

9.4 On the basis of 9.3 above there are the following four possible situations for valves of the air pipes and valves of the suction pipes:

Case	Suction Valve	Air Pipe Valve
1	Open	Open
2	Open	Closed
3	Closed	Open
4	Closed	Closed

Case 1 is not likely since there are air pockets of different depths in different tanks.

Assuming the increase in the content of tanks PT1, PT2 and ST1 may have occurred after the damage due to bottom contact, Case 4 would imply that about 3000 LT of flooding occurred to each lower hull before the capsize. This (and the corresponding large increase in draft) is not credible.

Case 2 would imply that sea water has flowed through the suction pipes of the damaged forward tanks until the air pockets, in those tanks which were partly filled, compressed to the local hydrostatic pressure. Thereafter, the pipe system might allow some escape of air from air pockets.

The suction pipes from the No. 1 tanks penetrate the tank bulkhead 4.7 ft. above (now below) the keel, and therefore are now about 107.7 ft. below the sea surface. For any tank which had an air pocket extending below this level there would be a possibility for some escape of air. The tanks which have the largest air pockets according to the acoustic soundings, PT10, PT6 and ST6, have liquid levels which correspond closely to 107.7 ft. below the sea surface. Therefore Case 2

cont'd ...

cannot be excluded as a possibility, though, because of possible leakage of air as described, Case 2 does not enable a reconstruction of the pre-capsize contents of individual tanks to be made.

9.5 For Case 3 of 9.4 above (air pipes assumed open and suction valves assumed closed) calculations have been made to estimate the possible inflow (or outflow) from each tank prior to the capsize. These are included on Table 6A, Table 6B and Table 6C (notes).

Table 6A applies the Case 3 assumptions to the four drill water and four fuel oil tanks. Only one tank, ST6, has an air pocket close to the expected size.

The figures in square brackets on Table 6A show the values of acoustic soundings which would have corresponded with the anticipated size of air pocket. If an assumption is made that a small error, not exceeding 12 inches, might exist in acoustic soundings, then three more tanks ST5, PT13 and PT6 have air pockets of the expected size.

Table 6B applies the Case 3 assumption to the ballast tanks which have air pockets. It will be seen that the Case 3 assumptions are not valid for tank PT10. If the air pocket in that tank is at hydrostatic pressure then, when it is expanded to atmospheric pressure, we have an air volume which is larger than the tank. The other possibilities are: Case 4, i.e. the air pocket is not at hydrostatic pressure because the suction valves and air pipe valves are closed.

Case 2 with an extra assumption that if suction valves of the damaged tanks are open the suction valve of tank PT10 must be closed.

A further possibility must be that tank P10 was, before the capsize, connected to one of the forward tanks now damaged and the suction valve of PT10 and of the damaged tank have remained open. When the damage occurred the sudden increase in pressure in the damaged tank caused some of the air originally in that tank to pass through the ballast system to tank PT10. Thus the air in PT10 may now be at hydrostatic pressure, but some of that air was originally in another tank.

10. Possible Ballast Transfers

10.1 From the position of the rig on the sea bed following the capsize it seems that the capsize occurred in a bow-down direction. A major probability must be that, by some accidental reason, two (or more) ballast tanks were interconnected by open suction valves such that water flowed as dictated by gravity between two or more different tanks and the relative position, fore and aft, of the tanks was such that a bow-down trim resulted from this transfer of water ballast.

10.2 As, according to the acoustic soundings, tank PT10 had the largest air pocket after the capsize and this tank is believed to have been full before the accident this tank could possibly be a tank from which water transferred prior to the accident. If it is assumed not more than two valves were open, i.e. that tank PT10 was interconnected to one other tank, the likely candidates for the other tank would seem to be PT4 or PT1.

Computations have been made to examine the righting moment curves of the rig following assumed transfers of ballast, by gravity, from PT10 to PT4 and alternatively from PT10 to PT1. For the purpose of standardisation with some other flooding scenarios made at an earlier stage of this investigation, an initial level draft of 80 ft. and a VCG of 63 ft. have been assumed. (These figures are very close to the estimate of draft and VCGL on Table 5.)

The results of the computations are shown at Figure 8 and Figure 9. In order that the righting moment curves are valid for angles of trim greater than the equilibrium positions the maximum feasible transfer of ballast has been assumed. In the case of transfer from PT10 to PT4 the limiting factor would be the stage where the water level in PT10 reaches the bellmouth of the suction pipe. With allowance for mooring restraint the theoretical calm water equilibrium angle would be approximately 11 degrees and the transfer of ballast approximately 610 LT. Rig motion and consequent motion of the liquid surface in tank PT10 would probably cause air to enter the suction pipe of PT10, terminating the siphonage to PT4, at a slightly earlier stage.

In the case of transfer from PT10 to PT1, and allowing for mooring restraint, the limit to the transfer of ballast would occur when the liquid surface in PT10 and in the upper part of PT1 (which is located in the stability cone part of the Port foward column) are equidistant below the waterplane of the rig. This would occur at about 11.8 degrees trim after a transfer of 434 LT of ballast.

Estimates have been made of the approximate time needed for for the gravity flooding from PT10 to PT4 or from PT10 to PT1. These are shown on Figure 8 and Figure 9 respectively. (It is assumed that the suction valves of both tanks were fully open).

cont'd ...

10.3 At an angle of trim of 11 degrees the distance from the waterplane of the rig to the lowest downflooding point would have reduced from 71.5 ft. to 44 ft. as shown by the curve marked 6 on Figure 8 and Figure 9. Similarly the air gap in way of the fore end of the upper hull would have reduced from 50 ft. to about 22.5 ft.

It would be necessary to use model tests to determine whether any occurrences of green water on the upper deck could be expected, under the reported wave conditions, at this angle of trim. In the event of such occurrences additional intermittent flooding into the forward chain lockers would progressively increase the angle of trim causing more frequent flooding of the chain lockers. If the forward chain lockers flooded completely the stability of the rig would be dependant on the buoyancy of the upper hull and the angle of trim would then be about 23 degrees (curve 4 on Figure 8 and Figure 9). In the event of loss of the buoyancy of the upper hull, due perhaps to flooding via the ventilation systems, a capsize would occur.

10.4 There are, of course, various other possibilities for transfer of ballast, by gravity, between two tanks and if the tanks in question were at, or near, opposite ends of a lower hull a larger trim would result from the transfer. There is also the further possibility that the number of inter-connected tanks may have been more than two. As indicated in part 9 above there are several possible circumstances which could have made it impossible to deduce the contents of tanks at the time of the capsize from the results of the acoustic soundings.

Thus 10.2 above considers possible transfers of ballast from PT10 (which is suggested by the large air pocket in that tank at the time of the acoustic soundings) but some other or additional transfer (which is not suggested by acoustic soundings) might have occurred.

11. Sundry Considerations

11.1 Following breakage of the portlight of the ballast control room and splashing of the ballast control panels, seepage of water past the push buttons would explain the reported involuntary opening of valves.

However, it provides no obvious explanation for the reason why, apparently, at least two ballast valves were either not closed (or not fully closed) several hours after the breakage of the portlight.

Switching off the ballast control panels should have de-energised all of the solenoids and caused closure of the valves in the pump rooms. With the panels switched off, the valve position indicator lights would also go off. In that situation it would seem most likely that the control room operator would have sent someone (or would have gone himself) to the pump rooms to make sure that all valves were closed.

An electrician would have needed to switch the ballast panels on, at least from time to time, in order to identify and rectify the faults. At those times the valve position indicator lights should have shown the status, open or closed, of all valves.

Accordingly we can offer no explanation for the open valves and it is hoped that other parties who have been considering this problem, and who may possibly have some further information perhaps from the divers' examination of the control room, or perhaps from more detailed drawings of the vital components, will have been more successful.

11.2 The ballast pumps were located aft. With a small bow-down trim the possibility of de-ballasting from forward tanks is improved by pumping from two or more tanks simultaneously rather than from a single tank. The control room operators may not have been aware of this and this procedure is not suggested by the Booklet of Operating Conditions.

11.3 The chain lockers of each corner column of 'Ocean Ranger' together with their three chain pipes and six wire rope trunks have a capacity such that they would contain approximately 1160 LT of sea water if flooded. The total area at upper deck level of the three chain pipes and six wire rope trunks is approximately 90 square ft. These openings would have been defined as 'downflooding points' for intact and damage stability calculations. Accordingly there would have been no necessity, or incentive, to consider the fitting of some special devices to restrict flooding through these openings at upper deck level.

11.4 It is envisaged that all of the ventilation intakes and outlets serving the upper hull and compartments within the columns would have been fitted with some type of closing

cont'd ...

appliance. Some of these may have been self-acting, i.e. float valves, others would have been manually operated, e.g. hinged gasketted covers which can be manually closed and secured in that position by clips or toggles.
It must be observed, however, that ventilator closing appliances of semi-submersible units tend to remain open at all times for the reason that ventilation is required at all times.

11.5 Items 11.2, 11.3 and 11.4 above mention aspects which seem to have some relevance to the accident. The corresponding features of 'Ocean Ranger' fully satisfied the requirements of the Rules and Regulations which applied. A need for some further consideration of the requirements of Rules and Regulations may be indicated by this accident.

11.6 Although the message from the rig at 01.00 hours NST stated 'listing bow down', subsequent messages from the rig at 01.05 and 01.08 hours NST referred to a list to Port. It is envisaged that the rig may have been bow down with a small heel to Port at the time of these messages.

11.7 Several experimeters who have carried out model tests on semi-submersible units have found that, due to hydrodynamic phenomena, the mean position of a model can depart from the upright when the model is afloat in regular waves of a particular period. This has become known as the 'tilt phenomenon'. Some possibility may exist that the listing of 'Ocean Ranger' which can be predicted by hydrostatic considerations was further increased by some hydrodynamic effect (which could be identified only by model tests). The high position of the mooring fairleads might be a factor which caused the rig to be sensitive to such effects.

cont'd ...

12. Conclusions

12.1 The 'Ocean Ranger' Booklet of Operating Conditions

The Booklet contains all the information and data it should provide.

Our independent check of the curves of allowable VCG resulted in values slightly lower than those in the Booklet in regard to compliance with the intact stability criteria with assumed wind speeds of 70 knots or 100 knots. These allowable VCG values are particularly sensitive to the results of wind moment calculations and are, therefore, dependent on the detail interpretation of the parts of the Stability Rules or Regulations concerning calculation of wind moment. The method for calculation of wind moment as given in ABS Rules or USCG regulations is not comprehensive and definitive to such extent that a conclusion can be made about the small difference which exists between the allowable VCG values in the Booklet and those which we obtain by our independent check.

The Booklet is of a commendable high standard in regard to legibility, accuracy and completeness of the information it provides. We conclude that the Booklet satisfies all requirements of ABS and the USCG.

12.2 Draft and Centre of Gravity of 'Ocean Ranger' on 14th February prior to the Accident

From the various documents received we estimate the draft and VCG to have been as shown on Table 5 of this report, i.e.

draft, ... about 78.9 ft.
VCG corrected for transverse free surface (VCGT)
... about 62.6 ft.
VCG corrected for longitudinal free surface (VCGL)
... about 63.3 ft.

We therefore conclude 'Ocean Ranger' complied with the stability requirements for operating conditions.

We conclude that it would have been necessary for 'Ocean Ranger' to be de-ballasted to a lesser draft in order to comply with the stability requirements for survival conditions. Using wind speed as the relevant parameter, on the basis of the information available it would not have been necessary for 'Ocean Ranger' to have changed to the survival condition. A semi-submersible unit should, in general, be de-ballasted to survival draft if an air gap cannot otherwise be maintained between the crests of the highest waves and the underside of the upper hull. We do not have any reason to suppose that 'Ocean Ranger' was unable to maintain an air gap.

cont'd ...

We therefore conclude that 'Ocean Ranger' satisfied the stability requirements of both the ABS and USCG at the time of the accident.

12.3 Probable Cause of the Accident

The most probable mode of the capsize and sinking was by downflooding of the chain lockers of the Port and Starboard forward columns followed by flooding to the upper hull and some parts of columns.

The most probable cause of the downflooding was the occurrence of a list or trim sufficient to allow some intermittent wave contact with the forward part of the upper hull.

The most probable cause which can be envisaged for the occurrence of a bow-down trim is that two (or more) valves of the ballast system were accidentally open such that ballast was able to flow by gravity from one (or more) tanks which were full or nearly full, to one or more other tanks which were empty or partly empty and which were at a more forward position.

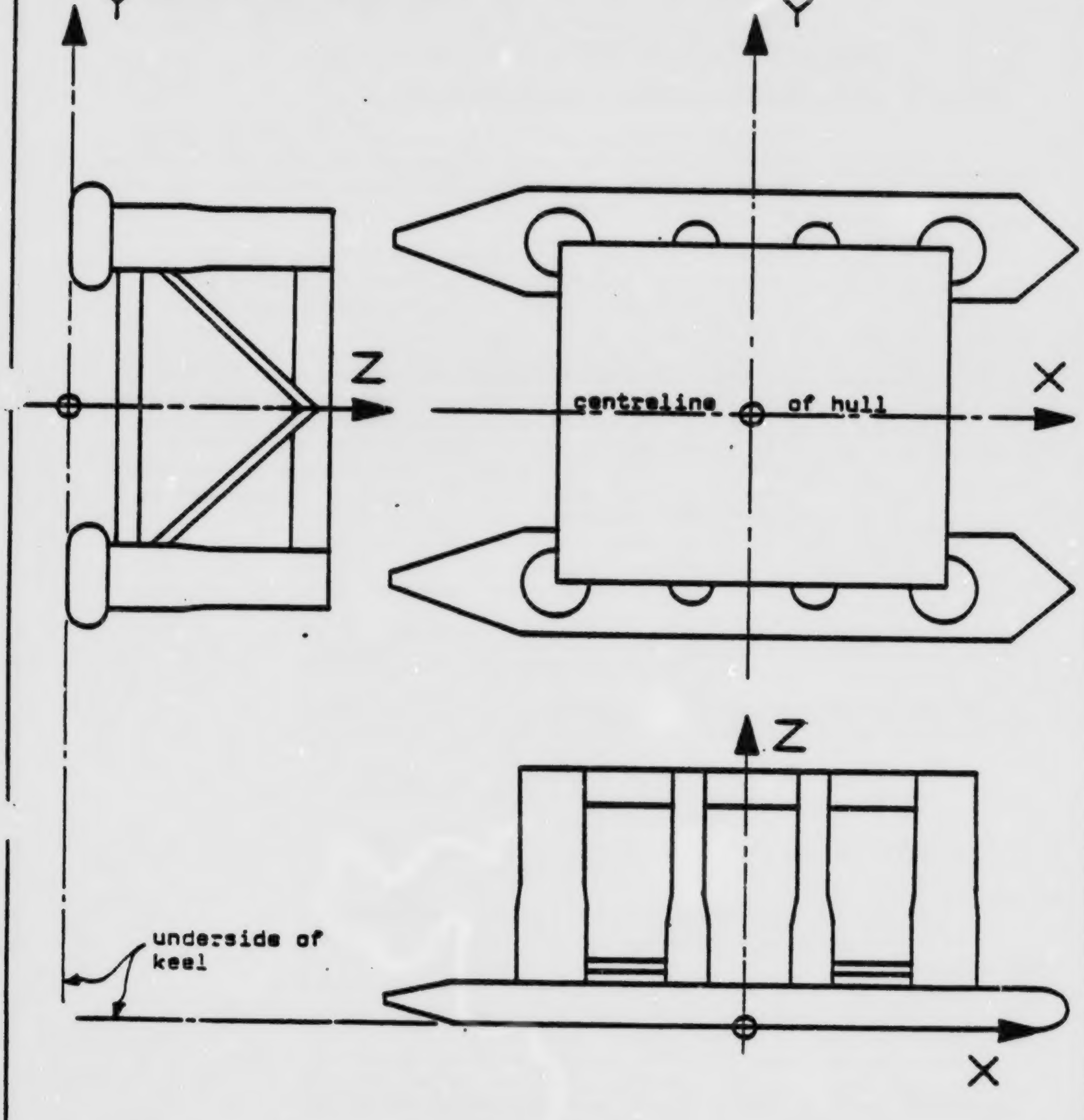
Y
Y
Z
X
centreline of hull
Z
underside of keel
X

FIG. 1 POSITIONS AND DIRECTIONS OF CO-ORDINATE AXES

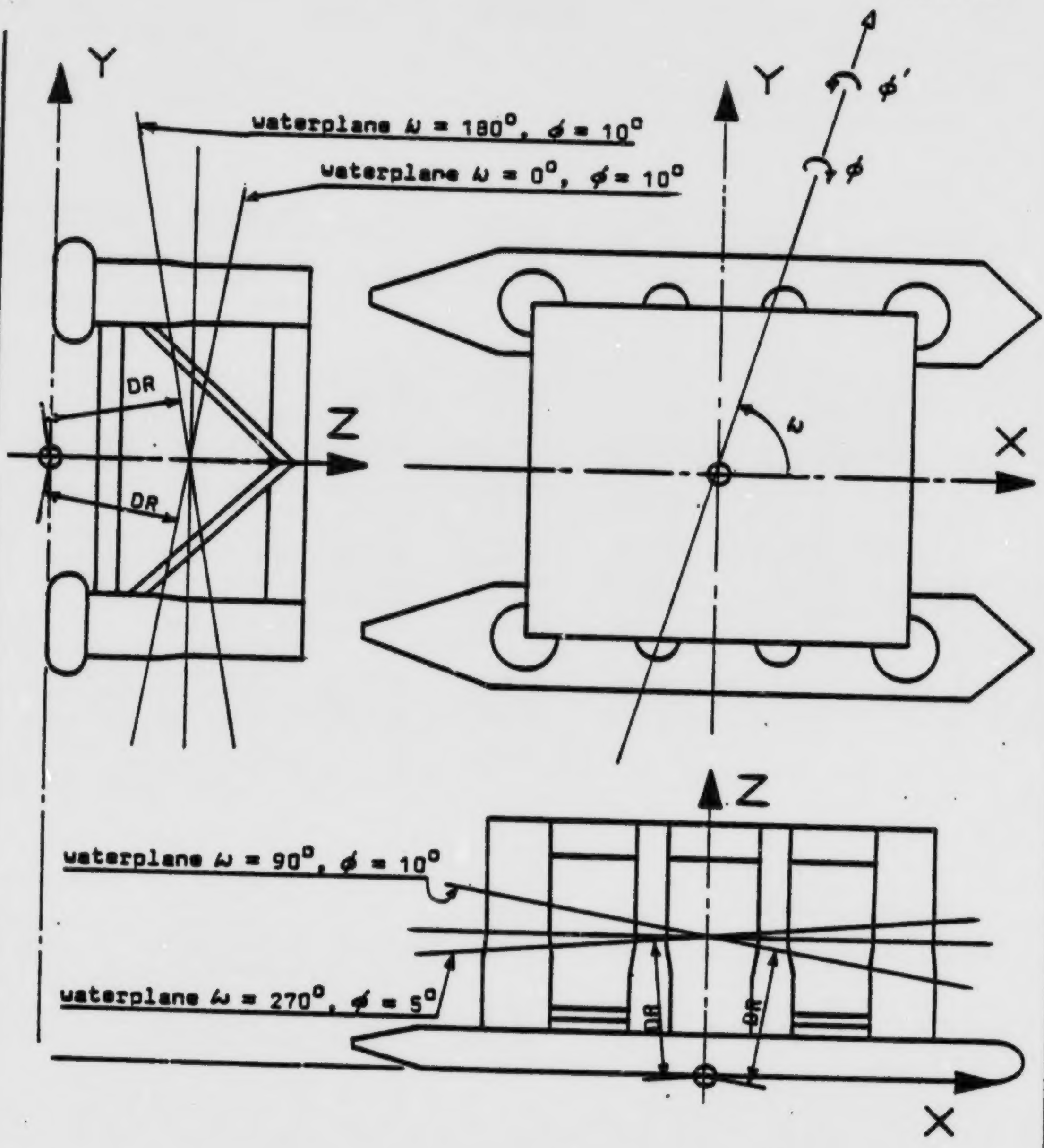
Y
waterplane ω = 180°, φ = 10°
waterplane ω = 0°, φ = 10°
DR
DR
Z
Y
φ'
φ
ω
X
Z
waterplane ω = 90°, φ = 10°
waterplane ω = 270°, φ = 5°
DR
DR
X

FIG. 2 DEFINITION OF ANGLE ω (W), ANGLE φ (FI), AND DIMENSION 'DR'

Note.

φ shows inclination of waterplane relative to rig

φ' shows inclination of rig relative to waterplane.

TABLE 1

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OCEAN RANGER

  HYDROSTATIC DATA
  ****************


                                                             --------------------------
   17.678    17.983    18.288    18.592    18.897  DRAFT (M)
                                                             --------------------------
 35260.53  35460.29  35659.13  35856.26  36053.39  DISPLACEMENT IN 1.0250
                                                   DENSITY S.W. (TONNES).

                                                   CENTRE OF BUOYANCY (M):-
    0.287     0.288     0.288     0.287     0.285  XB(=FORD)
    0.000     0.000     0.000     0.000     0.000  YB(=TO PORT)
    5.730     5.798     5.867     5.936     6.006  ZB(=VERTICAL)

  640.967   637.943   632.537   631.025   631.025  WATERPLANE AREA (M2)
    0.626     0.438     0.096    -0.000    -0.000  XA (M)
   -0.000    -0.000    -0.000    -0.000    -0.000  YA (M)

   591999    588883    583552    581851    581564  IX'   ) SECOND
   569251    564456    555748    553303    553303  IY'   ) MOMENT OF
   569251    564455    555748    553302    553303  IU    ) W'PLANE
   591998    588882    583551    581851    581564  IV    ) AREA (M4)
  0.0       0.0       0.0       0.0       0.0      COSINE OF ANGLE BETWEEN
                                                   X AND U AXES.
   22.278    22.114    21.842    21.753    21.737  MINIMUM KM (KMU) (M)
   22.939    22.820    22.641    22.569    22.540  MAXIMUM KM (KMV) (M)




                                                             --------------------------
    58.00     59.00     60.00     61.00     62.00  DRAFT (FT)
                                                             --------------------------
 34705.30  34901.91  35097.63  35291.65  35485.58  DISPLACEMENT IN 1.025
                                                   DENSITY S.W. (L.T.)

    73.09     72.55     71.66     71.37     71.31  MINIMUM KM (KMU) (FT)
    75.26     74.87     74.28     74.05     73.95  MAXIMUM KM (KMV) (FT)
```

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OCEAN RANGER

  HYDROSTATIC DATA
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                                                             --------------------------
   19.202     19.507     19.812     20.116     20.421    DRAFT (M)
                                                             --------------------------
 36250.55   36446.91   36640.90   36832.58   37021.93    DISPLACEMENT IN 1.0250
                                                             DENSITY S.W. (TONNES).

                                                             CENTRE OF BUOYANCY (M):-
    0.284      0.282      0.281      0.279      0.278    XB(=FORD)
    0.000      0.000      0.000      0.000      0.000    YB(=TO PORT)
    6.077      6.149      6.220      6.292      6.363    ZB(=VERTICAL)

  631.025    624.797    617.228    609.792    602.530    WATERPLANE AREA (M2)
   -0.000     -0.000     -0.000     -0.000     -0.000    XA (M)
   -0.000     -0.000     -0.000     -0.000     -0.000    YA (M)

   581279     575167     567805     560590     553538    IX'   ) SECOND
   553303     552549     551635     550709     549814    IY'   ) MOMENT OF
   553302     552548     551635     550708     549813    IU    ) W'PLANE
   581279     575167     567805     560590     553538    IV    ) AREA (M4)
  0.0        0.0        0.0        0.0        0.0        COSINE OF ANGLE BETWEEN
                                                             X AND U AXES.
   21.722     21.688     21.652     21.617     21.586    MINIMUM KM (KMU) (M)
   22.513     22.324     22.104     21.892     21.689    MAXIMUM KM (KMV) (M)




                                                             --------------------------
    63.00      64.00      65.00      66.00      67.00    DRAFT (FT)
                                                             --------------------------
 35679.74   35873.00   36063.95   36252.61   36438.98    DISPLACEMENT IN 1.025
                                                             DENSITY S.W. (L.T.)

    71.27      71.16      71.04      70.92      70.82    MINIMUM KM (KMU) (FT)
    73.86      73.24      72.52      71.83      71.15    MAXIMUM KM (KMV) (FT)
```

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OCEAN RANGER

  HYDROSTATIC DATA
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                                                           --------------------------
    20.726     21.031     21.336     21.640     21.945   DRAFT (M)
                                                           --------------------------
  37215.87   37412.98   37608.66   37802.57   37993.79   DISPLACEMENT IN 1.0250
                                                           DENSITY S.W. (TONNES).

                                                           CENTRE OF BUOYANCY (M):-
     0.276      0.275      0.274      0.272      0.271   XB(=FORD)
    -0.000     -0.000     -0.000     -0.000     -0.000   YB(=TO PORT)
     6.437      6.513      6.590      6.666      6.742   ZB(=VERTICAL)

   633.258    628.600    624.098    616.395    607.345   WATERPLANE AREA (M2)
    -0.000     -0.000     -0.000     -0.000     -0.000   XA (M)
    -0.000     -0.000     -0.000      0.0       -0.000   YA (M)

    589737     585505     581419     574295     566357   IX'   ) SECOND
    553364     552782     552214     547616     541926   IY'   ) MOMENT OF
    553364     552782     552214     547616     541925   IU    ) W'PLANE
    589737     585505     581418     574295     566357   IV    ) AREA (M4)
   0.0        0.0        0.0        0.0        0.0       COSINE OF ANGLE BETWEEN
                                                           X AND U AXES.
    21.678     21.658     21.640     21.515     21.360   MINIMUM KM (KMU) (M)
    22.680     22.555     22.436     22.239     22.022   MAXIMUM KM (KMV) (M)




                                                           --------------------------
     68.00      69.00      70.00      71.00      72.00   DRAFT (FT)
                                                           --------------------------
  36629.86   36823.86   37016.46   37207.32   37395.52   DISPLACEMENT IN 1.025
                                                           DENSITY S.W. (L.T.)

     71.12      71.06      71.00      70.59      70.08   MINIMUM KM (KMU) (FT)
     74.41      74.00      73.61      72.96      72.25   MAXIMUM KM (KMV) (FT)
```

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OCEAN RANGER

  HYDROSTATIC DATA
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                                                          --------------------------
  22.250     22.555     22.860     23.164     23.469    DRAFT (M)
                                                          --------------------------
38182.39   38368.38   38551.87   38732.91   38911.52    DISPLACEMENT IN 1.0250
                                                          DENSITY S.W. (TONNES).

                                                          CENTRE OF BUOYANCY (M):-
   0.269      0.268      0.267      0.266      0.264    XB(=FORD)
  -0.000     -0.000     -0.000     -0.000     -0.000    YB(=TO PORT)
   6.818      6.894      6.969      7.044      7.119    ZB(=VERTICAL)

 599.483    591.310    583.322    575.521    569.415    WATERPLANE AREA (M2)
  -0.000     -0.000     -0.000     -0.000     -0.000    XA (M)
   0.0       -0.000     -0.000     -0.000     -0.000    YA (M)

  558591     550995     543571     536317     530496    IX'   ) SECOND
  536086     530396     524755     519163     513880    IY'   ) MOMENT OF
  536086     530396     524755     519162     513880    IU    ) W'PLANE
  558590     550995     543570     536317     530496    IV    ) AREA (M4)
 0.0        0.0        0.0        0.0        0.0        COSINE OF ANGLE BETWEEN
                                                          X AND U AXES.
  21.209     21.063     20.921     20.793     20.655    MINIMUM KM (KMU) (M)
  21.813     21.613     21.421     21.237     21.093    MAXIMUM KM (KMV) (M)




                                                          --------------------------
   73.00      74.00      75.00      76.00      77.00    DRAFT (FT)
                                                          --------------------------
37581.16   37764.22   37944.82   38123.01   38298.80    DISPLACEMENT IN 1.025
                                                          DENSITY S.W. (L.T.)

   69.58      69.10      68.64      68.13      67.77    MINIMUM KM (KMU) (FT)
   71.57      70.91      70.28      69.67      69.20    MAXIMUM KM (KMV) (FT)
  HYDROSTATIC DATA
  ****************


                                                         --------------------------
  23.774    24.079    24.384    24.688    24.993        DRAFT (M)
                                                         --------------------------
39088.71  39264.64  39439.20  39612.84  39786.37        DISPLACEMENT IN 1.0250
                                                         DENSITY S.W. (TONNES).

                                                         CENTRE OF BUOYANCY (M):-
   0.263     0.262     0.261     0.260     0.259        XB(=FORD)
  -0.000    -0.000    -0.000    -0.000    -0.000        YB(=TO PORT)
   7.194     7.268     7.344     7.419     7.495        ZB(=VERTICAL)

 565.154   560.917   556.702   555.525   555.525        WATERPLANE AREA (M2)
  -0.000    -0.000    -0.000    -0.000    -0.000        XA (M)
  -0.000    -0.000    -0.000    -0.000    -0.000        YA (M)

  526241    522013    517811    516482    516267        IX'   ) SECOND
  508759    503666    498603    497189    497189        IY'   ) MOMENT OF
  508759    503666    498603    497189    497189        IU    ) W'PLANE
  526241    522013    517811    516482    516267        IV    ) AREA (M4)
0.0       0.0       0.0       0.0       0.0             COSINE OF ANGLE BETWEEN
                                                         X AND U AXES.
  20.534    20.417    20.302    20.284    20.304        MINIMUM KM (KMU) (M)
  20.993    20.896    20.801    20.783    20.795        MAXIMUM KM (KMV) (M)




                                                         --------------------------
   78.00     79.00     80.00     81.00     82.00        DRAFT (FT)
                                                         --------------------------
38473.20  38646.37  38818.18  38989.08  39159.88        DISPLACEMENT IN 1.025
                                                         DENSITY S.W. (L.T.)

   67.37     66.98     66.61     66.55     66.61        MINIMUM KM (KMU) (FT)
   68.87     68.56     68.25     68.19     68.23        MAXIMUM KM (KMV) (FT)
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OCEAN RANGER

  HYDROSTATIC DATA
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                                                              --------------------------
  25.298    25.603    25.908    26.212    26.517   DRAFT (M)
                                                              --------------------------
39959.96  40133.48  40307.07  40480.60  40654.19   DISPLACEMENT IN 1.0250
                                                              DENSITY S.W. (TONNES).

                                                              CENTRE OF BUOYANCY (M):-
   0.257     0.256     0.255     0.254     0.253   XB(=FORD)
  -0.000    -0.000    -0.000    -0.000    -0.000   YB(=TO PORT)
   7.572     7.649     7.727     7.805     7.885   ZB(=VERTICAL)

 555.525   555.525   555.525   555.525   555.525   WATERPLANE AREA (M2)
  -0.000    -0.000    -0.000    -0.000    -0.000   XA (M)
  -0.000    -0.000    -0.000    -0.000    -0.000   YA (M)

  516056    515848    515644    515443    515246   IX'   ) SECOND
  497189    497189    497189    497189    497189   IY'   ) MOMENT OF
  497189    497189    497189    497189    497189   IU    ) W'PLANE
  516056    515848    515644    515443    515246   IV    ) AREA (M4)
0.0       0.0       0.0       0.0       0.0        COSINE OF ANGLE BETWEEN
                                                              X AND U AXES.
  20.325    20.347    20.370    20.395    20.420   MINIMUM KM (KMU) (M)
  20.809    20.824    20.840    20.857    20.875   MAXIMUM KM (KMV) (M)




                                                              --------------------------
   83.00     84.00     85.00     86.00     87.00   DRAFT (FT)
                                                              --------------------------
39330.74  39501.52  39672.38  39843.18  40014.04   DISPLACEMENT IN 1.025
                                                              DENSITY S.W. (L.T.)

   66.68     66.76     66.83     66.91     67.00   MINIMUM KM (KMU) (FT)
   68.27     68.32     68.37     68.43     68.49   MAXIMUM KM (KMV) (FT)
```

```
OCEAN RANGER

   HYDROSTATIC DATA
   ****************


                                                           --------------------------
  26.822    27.127    27.432    27.736    28.041    DRAFT (M)
                                                           --------------------------
40827.72  41001.28  41174.57  41347.98  41521.29    DISPLACEMENT IN 1.0250
                                                    DENSITY S.W. (TONNES).

                                                    CENTRE OF BUOYANCY (M):-
   0.252     0.251     0.250     0.249     0.248    XB(=FORD)
  -0.000    -0.000    -0.000    -0.000    -0.000    YB(=TO PORT)
   7.965     8.045     8.126     8.208     8.290    ZB(=VERTICAL)

 555.525   554.903   554.903   554.903   554.799    WATERPLANE AREA (M2)
  -0.000    -0.000    -0.000    -0.000    -0.000    XA (M)
  -0.000    -0.000    -0.000    -0.000    -0.000    YA (M)

  515053    514275    514089    513906    513630    IX'   ) SECOND
  497189    496441    496441    496441    496428    IY'   ) MOMENT OF
  497189    496441    496441    496441    496428    IU    ) W'PLANE
  515053    514275    514089    513906    513630    IV    ) AREA (M4)
0.0       0.0       0.0       0.0       0.0         COSINE OF ANGLE BETWEEN
                                                    X AND U AXES.
  20.447    20.456    20.484    20.514    20.545    MINIMUM KM (KMU) (M)
  20.895    20.901    20.924    20.947    20.969    MAXIMUM KM (KMV) (M)




                                                           --------------------------
   88.00     89.00     90.00     91.00     92.00    DRAFT (FT)
                                                           --------------------------
40184.83  40355.66  40526.22  40696.91  40867.48    DISPLACEMENT IN 1.025
                                                    DENSITY S.W. (L.T.)

   67.08     67.11     67.21     67.30     67.40    MINIMUM KM (KMU) (FT)
   68.55     68.57     68.65     68.72     68.80    MAXIMUM KM (KMV) (FT)
```

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OCEAN R

  HYDRO DATA
  **********


                                                         --------------------------
  28.346.651    28.956     29.250      29.565     DRAFT (M)
                                                         --------------------------
41694.667.96  42041.25   42214.62    42381.01     DISPLACEMENT IN 1.0250
                                                  DENSITY S.W. (TONNES).

                                                  CENTRE OF BUOYANCY (M):-
   0.247.246     0.245      0.244       0.243     XB(=FORD)
  -0.000.000    -0.000     -0.000      -0.000     YB(=TO PORT)
   8.372.456     8.540      8.624       8.705     ZB(=VERTICAL)

 554.799.799   554.799    554.799     498.109     WATERPLANE AREA (M2)
  -0.000.000    -0.000     -0.000      -0.000     XA (M)
  -0.000.000    -0.000     -0.000      -0.000     YA (M)

513455.283.2  513114.7   512950.0    449163.7     IX'  ) SECOND
  496426428     496428     496429      489722     IY'  ) MOMENT OF
496428.428.9  496428.9   496425.9    449163.7     IU   ) W'PLANE
  513453283     513114     512950      489722     IV   ) AREA (M4)
0.0           0.0        0.0       -1.00000     COSINE OF ANGLE BETWEEN
                                                  X AND U AXES.
  20.576.609    20.643     20.679      19.569     MINIMUM KM (KMU) (M)
  20.991.022    21.050     21.079      20.550     MAXIMUM KM (KMV) (M)




                                                  --------------------------
   93.04.00      95.00      96.00       97.00     DRAFT (FT)
                                                  --------------------------
41038.18.70   41379.26   41549.90    41713.66     DISPLACEMENT IN 1.025
                                                  DENSITY S.W. (L.T.)

   67.57.62      67.73      67.84       64.20     MINIMUM KM (KMU) (FT)
   68.88.97      69.06      69.16       67.42     MAXIMUM KM (KMV) (FT)
```

TABLE 2

OCEAN RANGER **CO-ORDINATES OF DOWNFLOODING POINTS.**

GROUP 2 DOWNFLOODING POINTS (FOR AREA A+B HEEL)

POINT REF.	CO-ORDINATES (m)			REMARKS
NO. (NP)	X	Y	Z	
17	29.300	34.930	46.198	CHAIN PIPE NO. 1
18	35.850	37.080	46.198	CHAIN PIPE NO. 2
19	39.310	29.940	46.198	CHAIN PIPE NO. 3
20	40.120	-30.480	46.198	CHAIN PIPE NO. 4
21	35.810	-37.060	46.198	CHAIN PIPE NO. 5
22	29.550	-34.680	46.198	CHAIN PIPE NO. 6
23	-29.300	-34.930	46.198	CHAIN PIPE NO. 7
24	-35.850	-37.080	46.198	CHAIN PIPE NO. 8
25	-39.310	-29.940	46.198	CHAIN PIPE NO. 9
26	-40.120	30.480	46.198	CHAIN PIPE NO. 10
27	-35.810	37.060	46.198	CHAIN PIPE NO. 11
28	-29.550	34.680	46.198	CHAIN PIPE NO. 12

TABLE 3

OCEAN RANGER COMPUTATION OF ALLOWABLE VCG, INTACT, 80 FT DRAFT,
70 KNOT WIND.

```
   INTACT STABILITY   CALCULATION OF THE VERTICAL CENTRE OF GRAVITY
   TO SATISFY THE REQUIREMENT FOR THE AREA RATIO (A+B)/(B+C).
 --------------------------------------------------------------------------
DRAFT     DISPLAC      VOLUME      CENTRE OF GRAVITY            WIND    REQUIRED
                                   XG       YG        ZG        SPEED     RATIO
24.38   39439.47    38477.55     0.26    -0.00     20.00        36.00      1.30

IN THE FOLLOWING CALCULATION THE PRELIMINARY VCG (ZG AS STATED ABOVE) IS
REVISED TO GIVE THE REQUIREMENT FOR THE AREA RATIO. XG AND YG ARE NOT CHANGE


HEEL DIRECTION                  W     0.0      0.0      0.0    15.000   15.000   15.000
HEEL ANGLE                     FI     0.0    14.057   28.114    0.0     11.998   23.995
DRAFT                          DR   24.384   24.189   23.274   24.384   24.235   23.879
ANGLE OF DOWNFLOODING         FIF                     28.114                     23.995
DOWNFLOODING POINT             NP                       18                         27
WIND HEELING LEVER             HL    0.169    0.271    0.345    0.202    0.287    0.355
AREA (B+C)                    B+C    0.0      0.055    0.131    0.0      0.051    0.119
FOR PRELIMINARY VCG:-
 RIGHTING LEVER            ( GZ1     0.0      0.324    1.695    0.0      0.279    1.222
                           ( GZ2     0.0     -0.005   -0.152    0.0     -0.008   -0.296
 AREA (A+B)                   A+B    0.0      0.037    0.221    0.0      0.027    0.160
 REVISED VCG                  ZGM                     20.429                     20.057
FOR REVISED VCG:-
 RIGHTING LEVER               GZ1    0.0      0.220    1.492    0.0      0.268    1.199
 AREA (A+B)                   A+B    0.0      0.024    0.170    0.0      0.025    0.155
 IS FIF<SECOND INTERCEPT?


HEEL DIRECTION                  W   30.000   30.000   30.000   45.000   45.000   45.000
HEEL ANGLE                     FI     0.0    10.933   21.867    0.0     10.595   21.191
DRAFT                          DR   24.384   24.220   24.252   24.384   24.211   24.449
ANGLE OF DOWNFLOODING         FIF                     21.867                     21.191
DOWNFLOODING POINT             NP                       27                         27
WIND HEELING LEVER             HL    0.221    0.297    0.360    0.226    0.298    0.361
AREA (B+C)                    B+C    0.0      0.050    0.112    0.0      0.049    0.110
FOR PRELIMINARY VCG:-
 RIGHTING LEVER            ( GZ1     0.0      0.270    1.361    0.0      0.259    1.646
                           ( GZ2     0.0      0.010   -0.310    0.0      0.035   -0.143
 AREA (A+B)                   A+B    0.0      0.022    0.138    0.0      0.019    0.145
 REVISED VCG                  ZGM                     19.887                     20.028
FOR REVISED VCG:-
 RIGHTING LEVER               GZ1    0.0      0.291    1.403    0.0      0.254    1.636
 AREA (A+B)                   A+B    0.0      0.024    0.146    0.0      0.019    0.143
 IS FIF<SECOND INTERCEPT?
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(FOR DEFINITIONS AND UNITS PLEASE REFER TO SUBSEQUENT PAGES
HEADED "DESCRIPTION OF COMPUTER OUTPUT").

```
HEEL DIRECTION              #   60.000  60.000  60.000  75.000  75.000  75.000
HEEL ANGLE                 FI    0.0    10.827  21.655   0.0    11.466  22.933
DRAFT                      DR   24.384  24.185  24.492  24.384  24.154  24.373
ANGLE OF DOWNFLOODING     FIF                   21.655                  22.933
DOWNFLOODING POINT         NP                       26                      26
WIND HEELING LEVER         HL    0.217   0.290   0.355   0.194   0.271   0.340
AREA (B+C)                B+C    0.0     0.048   0.109   0.0     0.047   0.108
FOR PRELIMINARY VCG:-
 RIGHTING LEVER         ( GZ1    0.0     0.253   1.925   0.0     0.252   2.052
                        ( GZ2    0.0     0.352   0.144   0.0     0.046   0.355
 AREA (A+B)               A+B    0.0     0.018   0.160   0.0     0.018   0.178
 REVISED VCG              ZGM                   20.253                  20.482
FOR REVISED VCG:-
 RIGHTING LEVER           GZ1    0.0     0.206   1.832   0.0     0.156   1.864
 AREA (A+B)               A+B    0.0     0.013   0.142   0.0     0.008   0.140
 IS FIF<SECOND INTERCEPT?


HEEL DIRECTION              #   90.000  90.000  90.000 105.000 105.000 105.000
HEEL ANGLE                 FI    0.0    12.804  25.608   0.0    11.630  23.260
DRAFT                      DR   24.384  24.094  24.319  24.384  24.147  24.388
ANGLE OF DOWNFLOODING     FIF                   25.608                  23.260
DOWNFLOODING POINT         NP                       26                      25
WIND HEELING LEVER         HL    0.158   0.244   0.326   0.194   0.271   0.339
AREA (B+C)                B+C    0.0     0.045   0.109   0.0     0.047   0.109
FOR PRELIMINARY VCG:-
 RIGHTING LEVER         ( GZ1    0.0     0.299   3.088   0.0     0.259   2.193
                        ( GZ2    0.0    -0.000  -0.000   0.0    -0.047  -0.387
 AREA (A+B)               A+B    0.0     0.023   0.259   0.0     0.019   0.190
 REVISED VCG              ZGM                   21.196                  20.591
FOR REVISED VCG:-
 RIGHTING LEVER           GZ1    0.0     0.034   2.571   0.0     0.140   1.960
 AREA (A+B)               A+B    0.0    -0.007   0.141   0.0     0.007   0.142
 IS FIF<SECOND INTERCEPT?


HEEL DIRECTION              #  120.000 120.000 120.000 135.000 135.000 135.000
HEEL ANGLE                 FI    0.0    10.889  21.778   0.0    10.589  21.178
DRAFT                      DR   24.384  24.183  24.504  24.384  24.211  24.447
ANGLE OF DOWNFLOODING     FIF                   21.778                  21.178
DOWNFLOODING POINT         NP                       24                      24
WIND HEELING LEVER         HL    0.217   0.289   0.351   0.226   0.296   0.355
AREA (B+C)                B+C    0.0     0.048   0.109   0.0     0.048   0.109
FOR PRELIMINARY VCG:-
 RIGHTING LEVER         ( GZ1    0.0     0.256   1.977   0.0     0.258   1.641
                        ( GZ2    0.0    -0.053  -0.147   0.0    -0.035   0.142
 AREA (A+B)               A+B    0.0     0.018   0.164   0.0     0.019   0.144
 REVISED VCG              ZGM                   20.307                  20.040
FOR REVISED VCG:-
 RIGHTING LEVER           GZ1    0.0     0.198   1.863   0.0     0.251   1.627
 AREA (A+B)               A+B    0.0     0.013   0.142   0.0     0.018   0.141
 IS FIF<SECOND INTERCEPT?
```

```
HEEL DIRECTION                 #  150.000 150.000 150.000 165.000 165.000 155.000
HEEL ANGLE                    FI    0.0    10.928  21.855   0.0    11.992  23.983
DRAFT                         DR  24.384  24.220  24.251  24.384  24.235  23.890
ANGLE OF DOWNFLOODING        FIF                  21.855                  23.983
DOWNFLOODING POINT            NP                      24                      24
WIND HEELING LEVER            HL   0.221   0.295   0.353   0.202   0.284   0.346
AREA (B+C)                   B+C   0.0     0.049   0.111   0.0     0.051   0.118
FOR PRELIMINARY VCG:-
 RIGHTING LEVER          ( GZ1     0.0     0.270   1.357   0.0     0.279   1.219
                         ( GZ2     0.0    -0.010   0.309   0.0     0.008   0.295
 AREA (A+B)                  A+B   0.0     0.022   0.138   0.0     0.027   0.159
 REVISED VCG                 ZGM                  19.902                  20.071
FOR REVISED VCG:-
 RIGHTING LEVER              GZ1   0.0     0.288   1.399   0.0     0.264   1.190
 AREA (A+B)                  A+B   0.0     0.023   0.145   0.0     0.025   0.153
 IS FIF<SECOND INTERCEPT?


HEEL DIRECTION                 #  180.000 180.000 180.000 195.000 195.000 195.000
HEEL ANGLE                    FI    0.0    14.057  28.114   0.0    12.085  24.170
DRAFT                         DR  24.384  24.189  23.274  24.384  24.209  23.696
ANGLE OF DOWNFLOODING        FIF                  28.114                  24.170
DOWNFLOODING POINT            NP                      24                      21
WIND HEELING LEVER            HL   0.169   0.268   0.333   0.202   0.285   0.345
AREA (B+C)                   B+C   0.0     0.054   0.129   0.0     0.052   0.118
FOR PRELIMINARY VCG:-
 RIGHTING LEVER          ( GZ1     0.0     0.324   1.695   0.0     0.268   1.118
                         ( GZ2     0.0     0.005   0.152   0.0     0.003  -0.204
 AREA (A+B)                  A+B   0.0     0.037   0.221   0.0     0.027   0.138
 REVISED VCG                 ZGM                  20.451                  19.817
FOR REVISED VCG:-
 RIGHTING LEVER              GZ1   0.0     0.214   1.482   0.0     0.307   1.193
 AREA (A+B)                  A+B   0.0     0.024   0.168   0.0     0.031   0.154
 IS FIF<SECOND INTERCEPT?


HEEL DIRECTION                 #  210.000 210.000 210.000 225.000 225.000 225.000
HEEL ANGLE                    FI    0.0    11.003  22.006   0.0    10.643  21.296
DRAFT                         DR  24.384  24.181  24.098  24.384  24.163  24.340
ANGLE OF DOWNFLOODING        FIF                  22.006                  21.286
DOWNFLOODING POINT            NP                      21                      21
WIND HEELING LEVER            HL   0.221   0.295   0.350   0.226   0.296   0.350
AREA (B+C)                   B+C   0.0     0.050   0.112   0.0     0.049   0.109
FOR PRELIMINARY VCG:-
 RIGHTING LEVER          ( GZ1     0.0     0.247   1.294   0.0     0.227   1.626
                         ( GZ2     0.0     0.020  -0.307   0.0     0.040  -0.186
 AREA (A+B)                  A+B   0.0     0.021   0.123   0.0     0.018   0.131
 REVISED VCG                 ZGM                  19.686                  19.847
FOR REVISED VCG:-
 RIGHTING LEVER              GZ1   0.0     0.307   1.411   0.0     0.255   1.682
 AREA (A+B)                  A+B   0.0     0.027   0.146   0.0     0.021   0.142
 IS FIF<SECOND INTERCEPT?
```

```
HEEL DIRECTION                 *  240.000 240.000 240.000 255.000 255.000 255.000
HEEL ANGLE                    FI     0.0   10.869  21.739    0.0   11.516  23.031
DRAFT                         DR  24.384  24.132  24.399  24.384  24.104  24.268
ANGLE OF DOWNFLOODING        FIF                  21.739                  23.031
DOWNFLOODING POINT            NP                      20                      20
WIND HEELING LEVER            HL   0.217   0.286   0.342   0.194   0.267   0.326
AREA (B+C)                   B+C   0.0     0.048   0.108   0.0     0.047   0.106
FOR PRELIMINARY VCG:-
 RIGHTING LEVER          ( GZ1     0.0     0.217   1.930   0.0     0.219   2.098
                         ( GZ2     0.0     0.048   0.091   0.0     0.032   0.316
 AREA (A+B)                  A+B   0.0     0.017   0.150   0.0     0.017   0.174
 REVISED VCG                 ZGM                  20.139                  20.446
FOR REVISED VCG:-
 RIGHTING LEVER              GZ1   0.0     0.190   1.879   0.0     0.130   1.923
 AREA (A+B)                  A+B   0.0     0.015   0.140   0.0     0.008   0.138
 IS FIF<SECOND INTERCEPT?


HEEL DIRECTION                 *  270.000 270.000 270.000 285.000 285.000 285.000
HEEL ANGLE                    FI     0.0   12.853  25.706    0.0   11.681  23.362
DRAFT                         DR  24.384  24.014  24.223  24.384  24.093  24.281
ANGLE OF DOWNFLOODING        FIF                  25.706                  23.362
DOWNFLOODING POINT            NP                      20                      19
WIND HEELING LEVER            HL   0.158   0.239   0.311   0.194   0.268   0.330
AREA (B+C)                   B+C   0.0     0.045   0.137   0.0     0.047   0.109
FOR PRELIMINARY VCG:-
 RIGHTING LEVER          ( GZ1     0.0     0.254   3.205   0.0     0.224   2.239
                         ( GZ2     0.0     0.000   0.000   0.0    -0.033  -0.344
 AREA (A+B)                  A+B   0.0     0.022   0.264   0.0     0.018   0.186
 REVISED VCG                 ZGM                  21.272                  20.551
FOR REVISED VCG:-
 RIGHTING LEVER              GZ1   0.0    -0.029   2.654   0.0     0.113   2.020
 AREA (A+B)                  A+B   0.0    -0.010   0.139   0.0     0.007   0.141
 IS FIF<SECOND INTERCEPT?


HEEL DIRECTION                 *  300.000 300.000 300.000 315.000 315.000 315.000
HEEL ANGLE                    FI     0.0   10.931  21.863    0.0   10.637  21.274
DRAFT                         DR  24.384  24.128  24.410  24.384  24.163  24.339
ANGLE OF DOWNFLOODING        FIF                  21.863                  21.274
DOWNFLOODING POINT            NP                      18                      18
WIND HEELING LEVER            HL   0.217   0.288   0.347   0.226   0.297   0.355
AREA (B+C)                   B+C   0.0     0.048   0.109   0.0     0.049   0.109
FOR PRELIMINARY VCG:-
 RIGHTING LEVER          ( GZ1     0.0     0.218   1.982   0.0     0.227   1.621
                         ( GZ2     0.0    -0.048  -0.094   0.0    -0.040   0.185
 AREA (A+B)                  A+B   0.0     0.017   0.154   0.0     0.018   0.131
 REVISED VCG                 ZGM                  20.174                  19.831
FOR REVISED VCG:-
 RIGHTING LEVER              GZ1   0.0     0.185   1.917   0.0     0.258   1.683
 AREA (A+B)                  A+B   0.0     0.014   0.142   0.0     0.021   0.142
 IS FIF<SECOND INTERCEPT?
```

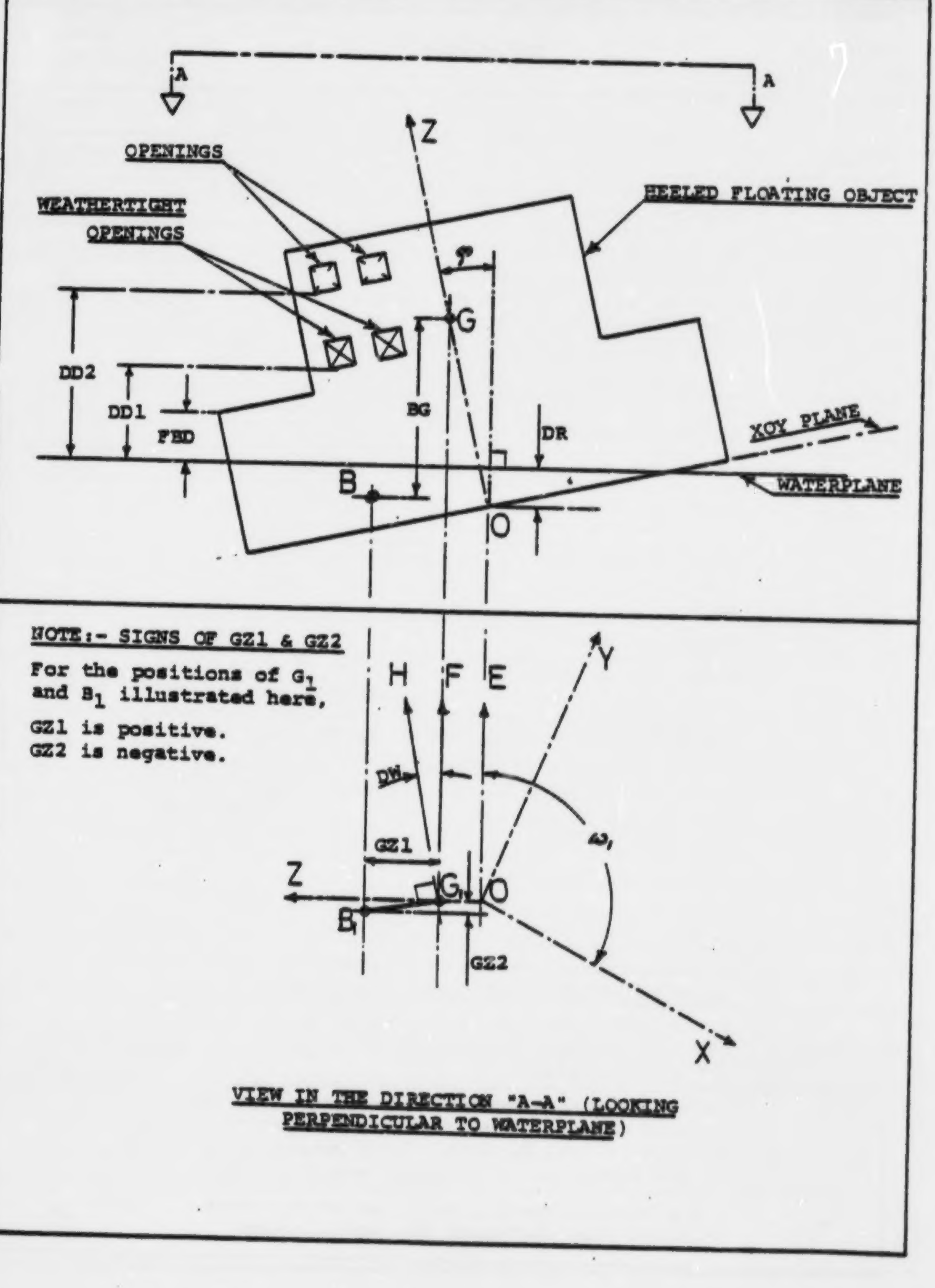
```
HEEL DIRECTION                *  330.000 330.000 330.000 345.000 345.000 345.000
HEEL ANGLE                   FI    0.0    10.997  21.994   0.0    12.080  24.159
DRAFT                        DR  24.384   24.181  24.096  24.384  24.209  23.696
ANGLE OF DOWNFLOODING       FIF                   21.994                  24.159
DOWNFLOODING POINT           NP                       18                      18
WIND HEELING LEVER           HL    0.221   0.296   0.357   0.202   0.287   0.354
AREA (B+C)                  B+C    0.0     0.050   0.113   0.0     0.052   0.120
FOR PRELIMINARY VCG:-
 RIGHTING LEVER           ( GZ1    0.0     0.247   1.290   0.0     0.268   1.115
                          ( GZ2    0.0    -0.020   0.306   0.0    -0.003   0.202
 AREA (A+B)                 A+B    0.0     0.021   0.122   0.0     0.027   0.138
 REVISED VCG                ZGM                   19.668                  19.798
FOR REVISED VCG:-
 RIGHTING LEVER             GZ1    0.0     0.310   1.414   0.0     0.311   1.198
 AREA (A+B)                 A+B    0.0     0.027   0.146   0.0     0.031   0.155
 IS FIF<SECOND INTERCEPT?
```

INTACT STABILITY; CALCULATION OF THE VERTICAL CENTRE OF GRAVITY TO SATISFY THE REQUIREMENT FOR THE AREA RATIO (A+B)/(B+C)

SUMMARY OF THE CALCULATIONS FOR 24.384 DRAFT

HEELING DIRECTION (#)	MAXIMUM VCG (ZGM)	REMARKS
0.0	20.429	
15.000	20.057	
30.000	19.887	
45.000	20.028	
60.000	20.253	
75.000	20.482	
90.000	21.196	
105.000	20.591	
120.000	20.307	
135.000	20.040	
150.000	19.902	
165.000	20.071	
180.000	20.451	
195.000	19.817	
210.000	19.686	
225.000	19.847	
240.000	20.139	
255.000	20.446	
270.000	21.272	
285.000	20.551	
300.000	20.174	
315.000	19.831	
330.000	19.668	
345.000	19.798	

FIG. A


A
A
Z
OPENINGS
WEATHERTIGHT OPENINGS
HEELED FLOATING OBJECT
φ
G
DD2
DD1
FBD
BG
DR
XOY PLANE
WATERPLANE
B
O
H
F
E
Y
DW
ω₁
GZ1
Z
G₁
O
B₁
GZ2
X

NOTE:- SIGNS OF GZ1 & GZ2

For the positions of G_1 and B_1 illustrated here,

GZ1 is positive.
GZ2 is negative.

VIEW IN THE DIRECTION "A-A" (LOOKING PERPENDICULAR TO WATERPLANE)

DESCRIPTION OF COMPUTER OUTPUT

PART 1 STABILITY CALCULATIONS - GENERAL DEFINITIONS

ITEM AT FIG. A	DEFINITION	COMPUTER OUTPUT SYMBOL
OX) OY) OZ)	Co-ordinate axes used to define the vessel.	
DR	Perpendicular distance from water surface to the co-ordinate origin (0, 0, 0).	DR
G and G1	Centre of gravity.	(XG, YG, ZG)
B and B1	Centre of buoyancy	
φ (phi)	Angle of heel.	FI
OE	Line showing the positive direction of the heeling axis.	
ω_1	Angle XOE measured in a plane parallel to the water surface.	
ω (omega)	Angle XOE measured in the XOY plane.	W
G_1F	Line through centre of gravity showing the positive direction of the heeling axis.	
G_1H	Line through centre of gravity showing the positive direction of the righting moment axis.	
B_1G_1	Righting lever GZ	GZ
GZ1	Component of righting lever in the direction perpendicular to the heeling axis direction.	GZ1
GZ2	Component of righting lever in the direction parallel to the heeling axis direction.	GZ2
BG	Vertical distance between centre of gravity and centre of buoyancy.	BG
DD1	Perpendicular distance from water surface to lowest progressive flooding point.	DD1
DD2	Perpendicular distance from water surface to lowest downflooding point.	DD2
FBD	Perpendicular distance from water surface to lowest freeboard reference point.	FBD
—	Table number of the downflooding point which has the smallest perpendicular distance to the water surface.	NP
—	GZW = GZ1 - HL where HL is heeling lever due to wind moment. Wind direction is perpendicular to heeling axis. Wind moment acts in the direction to increase angle of heel.	GZW
DW	Angle between heeling axis and moment axis = relative wind direction for equilibrium.	DW

DESCRIPTION OF COMPUTER OUTPUT

PART 2 MAXIMUM VCG TO SATISFY INTACT STABILITY REQUIREMENTS

COMPUTER OUTPUT SYMBOL	DEFINITION	UNITS (* = m)
DRAFT	Initial level draught of the platform.	*
DISPLAC	Displacement (weight) of the platform.	METRIC TONS
VOLUME	Displacement (volume)of the platform.	$*^3$
XG) YG) ZG)	Initial centre of gravity position. The horizontal position, XG, YG, gives level draught with zero wind moment. The vertical position ZG is a preliminary VCG; its choice does not affect the results of the calculations.	* * *
WIND SPEED	Required wind velocity for the intact stability calculations.	~~knots~~ * /sec.
REQUIRED RATIO	Required value of ((A+B)/(B+C)).	
W) F1) DR) GZ1) GZ2)	As defined in "DESCRIPTION OF COMPUTER OUTPUT, PART 1".	degrees degrees * * *
FIF	Angle of heel at which lowest downflooding point reaches the waterplane.	degrees
NP	Table number of the critical downflooding point. Details of the downflooding point are shown in the table "GROUP 2 DOWNFLOODING POINTS" which precedes the stability results.	
HL	Heeling lever due to wind moment.	*
B+C	Area under heeling lever curve.	*-rad.
A+B	Area under righting lever curve.	*-rad.
ZGM	Value of VCG such that ((A+B)/(B+C)) = REQUIRED RATIO.	*
IS FIF < SECOND INTERCEPT ?	If "NO" is stated the maximum angle of heel for measurement of A+B and B+C is controlled by the second intercept of righting lever and heeling lever curves.	

FIG 3 INTACT STABILITY. 80 FT. DRAFT. 70 KNOT WIND.

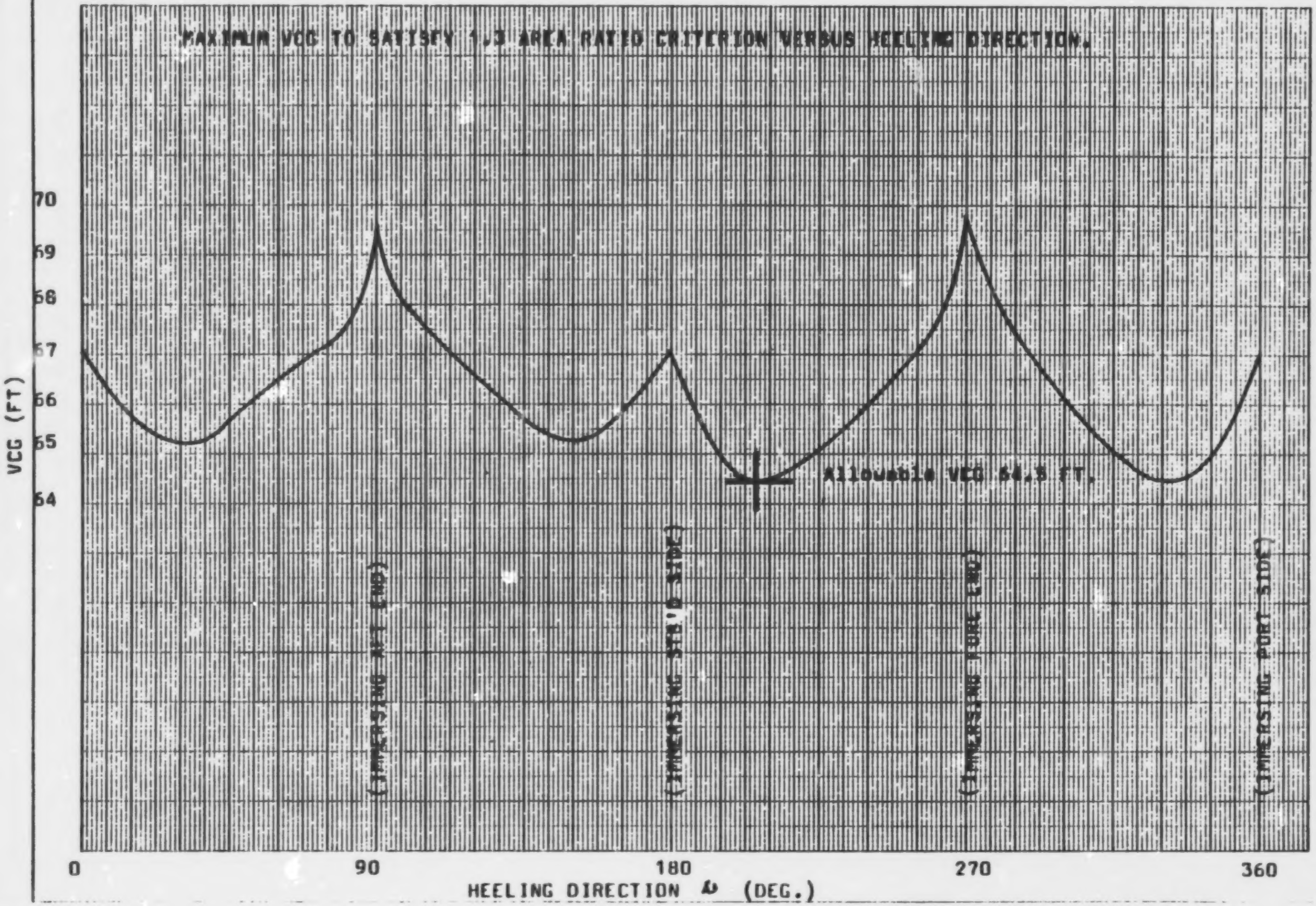


FIG 4. VERTICAL CENTRE OF GRAVITY VERSUS DRAFT

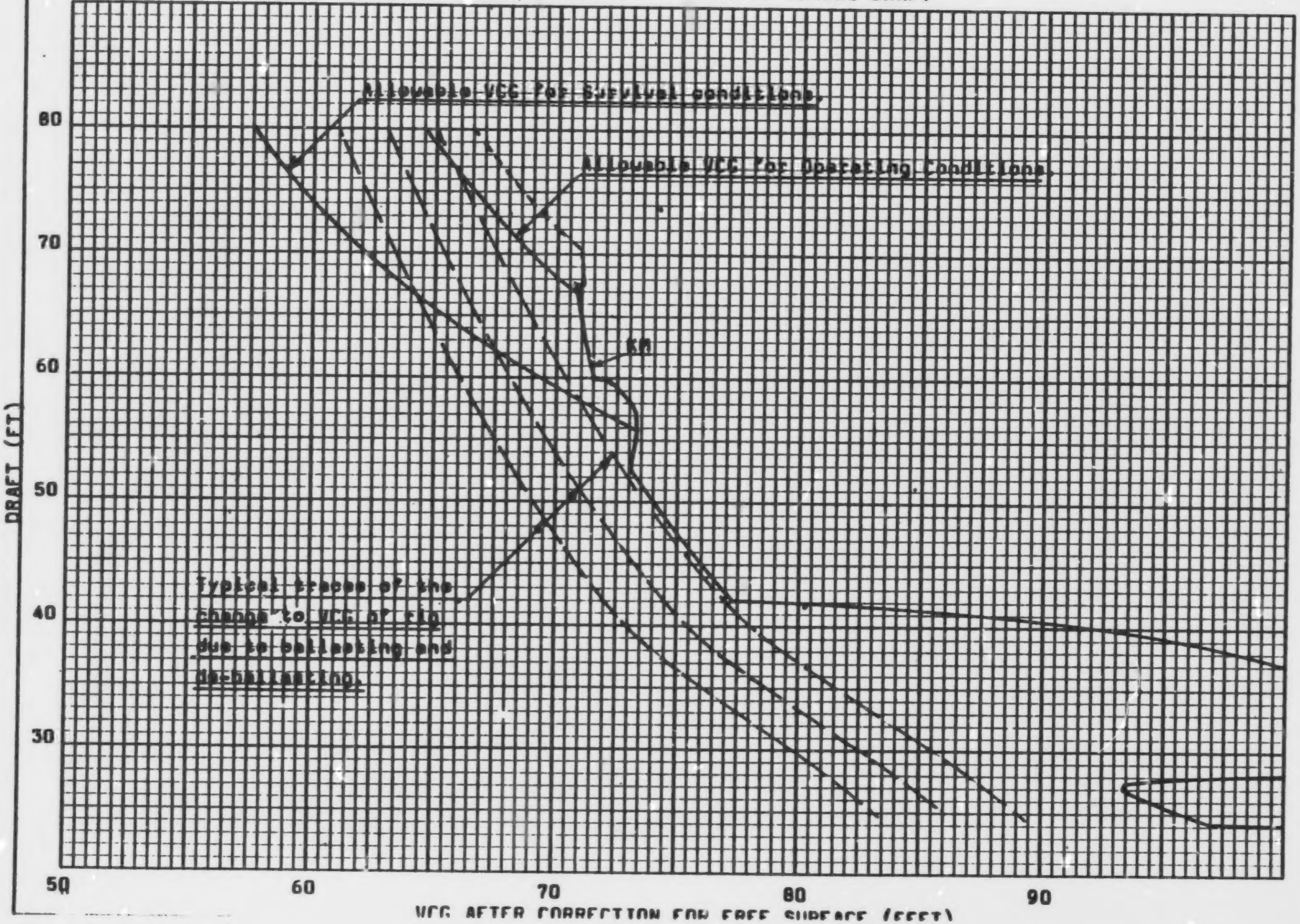


FIG. 5. RIGHTING AND HEELING ARM CURVES.

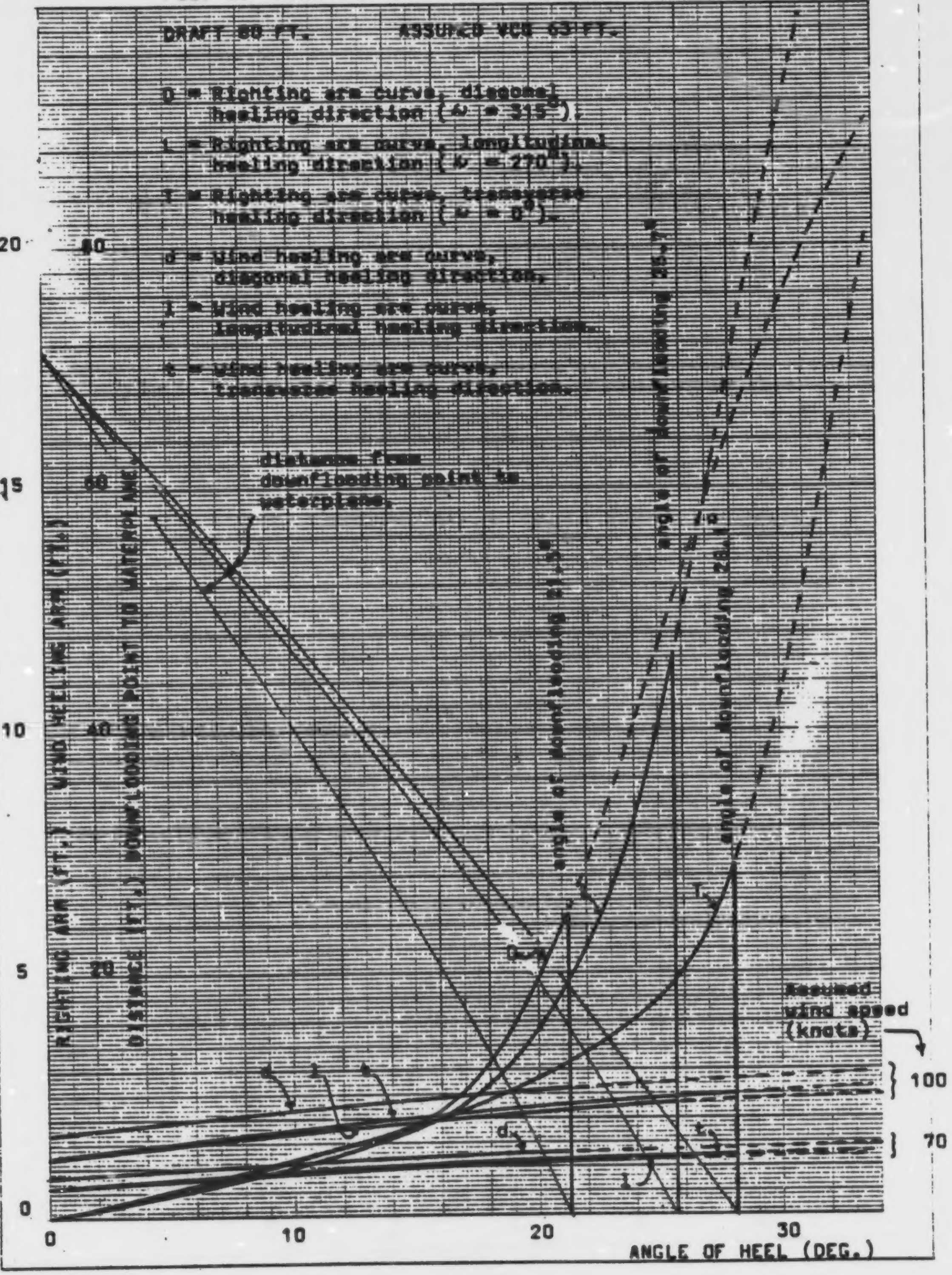


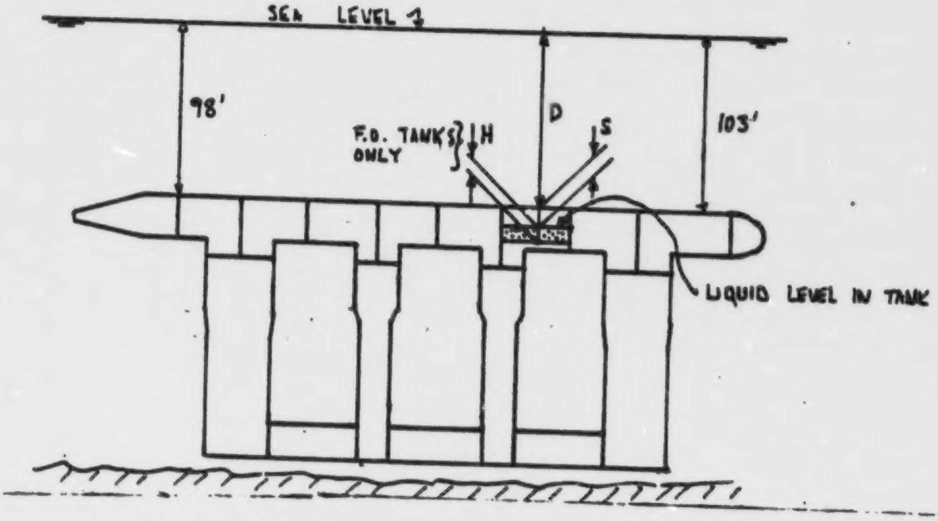
TABLE 4 SUMMARY OF LOADING REPORTS.

	DATE	DISPLACEMENT (LT)	VCG (FT)	TRANSV. FREE SURFACE CORR'N (FT)	VCG_T (FT)	LONGIT. FREE SURFACE CORR'N (FT)	VCG_L (FT)	LCG (FT)	TCG (FT)	DECK LOAD		FUEL OIL			POTABLE WATER (AT DECK) (LT)	S. W. (AT DECK) (LT)	DRILL WATER			$(VCG_L)-(VCG_T)$ (FT)
										Σ TABLES 2A & 2B (LT)	(LIQUIDS) Σ TABLE 3 (LT)	AT DECK (LT)	IN PONTOONS (LT)	TOTAL (LT)			AT DECK (LT)	IN PONTOONS (LT)	TOTAL (LT)	
STABILITY REPORTS	1982 25 JAN	38187	63.66	0.83	64.49	1.53	65.19	0.94 F	0.28 P	1955	863	148	573	721	151	112	103	656	759	0.70
	1 FEB	38930	63.70	0.72	64.42	1.47	65.17	0.82 F	0.54 S	1976	858	144	438	582	151	112	103	378	481	0.75
	9 FEB	39060	62.22	0.75	62.97	1.48	63.70	0.58 F	0.49 S	1633	833	148	423	571	155	112	103	789	892	0.73
MORNING REPORTS	9 FEB				63.77		63.4			1633	823			611	135				757	-0.37
	10 FEB				62.97		63.7			1637	835			600	134				725	0.73
	11 FEB				63.24		63.96			1679	850			617	153				975	0.72
CONTROL RM LOG AT 2400 HRS	11 FEB											135	413	548	153	112	103	1154	1257	
MORNING REPORTS	12 FEB				65.49		63.95			1679	849			604	166				973	-1.54
	13 FEB				64.49		64.21			1648	850			589	169				898	-0.28
	14 FEB				63.22		64.93			1648	816			571	179				879	1.71
STABILITY REPORT	14 FEB												546					959		

TABLE 5. ESTIMATED DISPLACEMENT AND CENTRE OF GRAVITY ON 14th February 1982.

	WEIGHT (LT)	VCG (FT)	LCG (+A /-F) (FT)	TCG (-P/+S) (FT)	LONGIT'L FREE SURFACE (FT × LT)	TRANSV. FREE SURFACE (FT × LT)
FROM 9 FEB 1982 STABILITY REPORT.						
SHEET 1	21523	87.373	5.078	1.179		
2A	662	106.618	-43.088	-8.265		
2B	971	162.12	-8.578	0.957		
3	833	138.596	21.238	-47.129	1015	2679
4	1319	4.768	32.469	-19.177	29769	15700
5	13589	12.589	-11.326	4.621	26962	10721
LT. WT. CORRECTION	200	145.8	0.	0.		
Σ	39097	62.166	-0.536	0.488	57746	29100
DRAFT = 80.88 FT						
KMT = 68.91 FT KML = 66.85 FT						
VCGT = 62.91 " VCGL = 63.64 "						
GMT = 6.00 " GML = 3.21 "						
DEDUCT LOWER HULL TANKS AS 9 FEB 1982 AND ADD LOWER HULL TANKS AS 14 FEB 1982						
9 FEB: BALLAST	-13589	12.589	-11.326	4.621	(-) 26962	(-) 10721
9 FEB: DRILL WATER & FUEL OIL	-1212	3.968	20.505	-20.853	(-) 29769	(-) 15700
14 FEB LOWER HULL TANKS	14586	11.615	-9.579	2.11	58958	29634
	38382	62.343	-0.813	0.317	59973	32318
REMOVE DRILL STRING FROM SET BACK						
	-134	220.3	0.	8.7		
14TH FEB. 1982 Σ	38748	61.797	-0.816	0.288	59973	32313
DRAFT = 78.92 FT						
KMT = 69.30 FT KML = 67.25 FT						
VCGT = 62.63 " VCGL = 63.34 "						
GMT = 6.67 " GML = 3.91 "						

NOTES TO TABLES 6A AND 6B.



CHECKS USING INFORMATION FROM DIVERS SURVEY.

Let V_0 = original air pocket in tank (ft^3), based on assumed tank contents on 14 Feb 1982.

Let V_2 = air pocket in tank, rig capsized, from divers acoustic sounding.

ASSUME (a) tank suction valve closed and (b) float valve of tank vent pipe open.

Pressure of air pocket in tank now governed by hydrostatic pressure at depth (D + S) ft. Let this be P_2 lbs/in^2 absolute. Expand the air pocket to atmospheric pressure, P_1 lbs/in^2 abs. Let the resultant volume be V_1 ft^3.

IF ASSUMPTIONS (a) and (b) are valid $(V_0 - V_1)/35$ would be an unexplained inflow (LT of sea water) before the capsize.

Calculation of V_1/V_2 for ballast and drill water tanks.

$$V_1/V_2 = P_2/P_1 = \frac{14.7 + (D + S)/2.25}{14.7}$$

Calculation of V_1/V_2 for fuel oil tanks. Let H = depth of fuel.

$$V_1/V_2 = P_2/P_1 = \frac{14.7 + (D + S + H)/2.25 - H/2.7}{14.7}$$

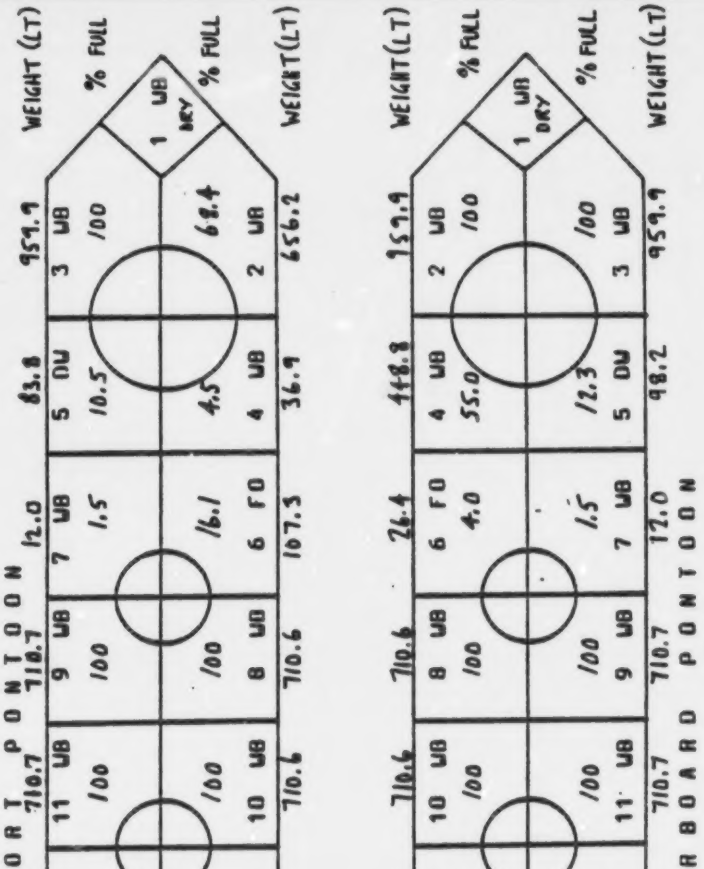
TABLE 6A

LIQUID	TANK	FULL CAPACITY	ON 14 FEB BEFORE ACCIDENT.		AFTER CAPSIZE						EQUIVALENT AIR POCKET BEFORE CAPSIZE	POSSIBLE INFLOW BEFORE CAPSIZE
		(FT³)	% FULL	AIR POCKET V_0 (FT³)	D (FT)	S (FT)	H (FT)	V_1/V_2	% FULL	AIR POCKET V_2 (FT³)	V_1 (FT³)	$(V_0 - V_1)/35$ (LT)
DRILL WATER 35.88 FT³/LT	PT 5	28629	10.5	25622	102	3 [6.0]		4.175 [4.265]	90.4 [79.0]	2752 [6007]	11490 [25622]	404
	ST 5	28629	12.3	25106	102	5 [5.9]		4.235 [4.265]	83.1 [79.4]	4847 [5886]	20527 [25106]	131
	PT 13	28245	62.8	10502	99.6	2 [2.6]		4.072 [4.090]	93.4 [91.1]	1864 [2534]	7590 [10502]	83
	ST 13	28245	35.8	18123	99.6	1 [4.4]		4.042 [4.144]	96.9 [84.6]	879 [4373]	3553 [18123]	416
FUEL OIL 42.3 FT³/LT	PT 6	28240	16.1	23701	101.4	6 [5.5]	3.8	4.266 [4.257]	77.9 [80.3]	6252 [5556]	26671 [23701]	-88
	ST 6	28240	4.0	27123	101.4	6	1.0	4.252	77.9	6252	26584	15
	PT 12	28240	26.3	20816	99.6	0.5 [4.8]	6.8	4.061 [4.191]	98.5 [82.4]	419 [4967]	1702 [20816]	546
	ST 12	28240	35.5	18219	99.6	1 [4.3]	8.9	4.086 [4.186]	96.9 [84.6]	880 [4852]	3596 [18219]	418

TABLE 6B

WATER BALLAST TANK	FULL CAPACITY	ON 14 FEB. BEFORE ACCIDENT		AFTER CAPSIZE					EQUIV-ALENT AIR POCKET BEFORE CAPSIZE	POSSIBLE CHANGE TO TANK CONTENT BEFORE CAPSIZE.
		% FULL	AIR POCKET V_0	D	S	V_1/V_2	% FULL	AIR POCKET V_2	V_1	$(V_0-V_1)/35$
	(FT³)		(FT³)	(FT)	(FT)			(FT³)	(FT³)	(LT)
PT 1	17927	0			0		100			+ 512
2	33596	68.4			0		100			+ 304
3	33596	100.			0		100			0
4	28581	4.5			0		100			+ 780
7	28245	1.5	27825	101.4	5	4.217	81.9	5103	21519	+ 180
8	24871	100.	0	100.7	1	4.075	96.9	770	3137	- 90
9	24874	100.	0	100.7	1	4.075	96.9	770	3137	- 90
10	24871	100.	0	100.2	7.5	4.262	71.8	7018	(29910)	(- 854)
11	24874	100.	0	100.2	1	4.060	96.9	770	3126	- 89
14	28591	69.7	9184	98.9	1	4.020	97.1	833	3349	+ 167
15	28626	100			0		100			0
16	12162	100	0	98.3	1.75	4.025	95.5	543	2186	- 62
ST 1	17929	0			0		100			+ 512
2	33596	100			0		100			0
3	33596	100			0		100			0
4	28581	55	12873	102.0	0.53	4.094	99.1	263	1077	+ 337
7	28245	1.5	27825	101.4	3	4.156	89.8	2870	11928	+ 454
8	24871	100	0	100.7	3	4.135	89.8	2534	10478	- 299
9	24874	100	0	100.7	3	4.135	89.8	2534	10478	- 299
10	24871	100	0	100.2	2	4.090	93.5	1624	6642	- 190
11	24874	100	0	100.2	0.5	4.045	98.5	368	1448	- 42
14	28587	57	12299	98.9	2	4.051	93.8	1764	7146	+ 147
15	28626	100	0	98.9	1	4.020	97.1	833	3349	- 96
16	12162	100	0	98.3	1	4.002	97.8	270	1081	- 31

O C E A N   R A N G E R


P O R T   P O N T O O N
WEIGHT (LT)
% FULL
347.5
16 WB
100
817.9
15 WB
100
494.5
13 DW
62.8
710.7
11 WB
100
710.7
9 WB
100
12.0
7 WB
1.5
83.8
5 DW
10.5
959.9
3 WB
100
1 WB
DRY
14 WB
67.9
554.2
12 FO
26.3
175.5
10 WB
100
710.6
8 WB
100
710.6
6 FO
16.1
107.3
4 WB
4.5
36.9
2 WB
68.4
656.2
S T A R B O A R D   P O N T O O N
465.2
14 WB
57.0
236.9
12 FO
35.5
710.6
10 WB
100
710.6
8 WB
100
26.4
6 FO
4.0
448.8
4 WB
55.0
959.9
2 WB
100
1 WB
DRY
16 WB
100
347.5
15 WB
100
817.9
13 DW
35.8
292.1
11 WB
100
710.7
9 WB
100
710.7
7 WB
1.5
12.0
5 DW
12.3
98.2
3 WB
100
959.9

WB = water ballast tank
DW = drill water tank
FO = fuel oil tank

FIG. 6. ASSUMED CONTENTS OF LOWER HULL TANKS ACCORDING TO THE STABILITY REPORT ON 14TH FEBRUARY 1982.

OCEAN RANGER

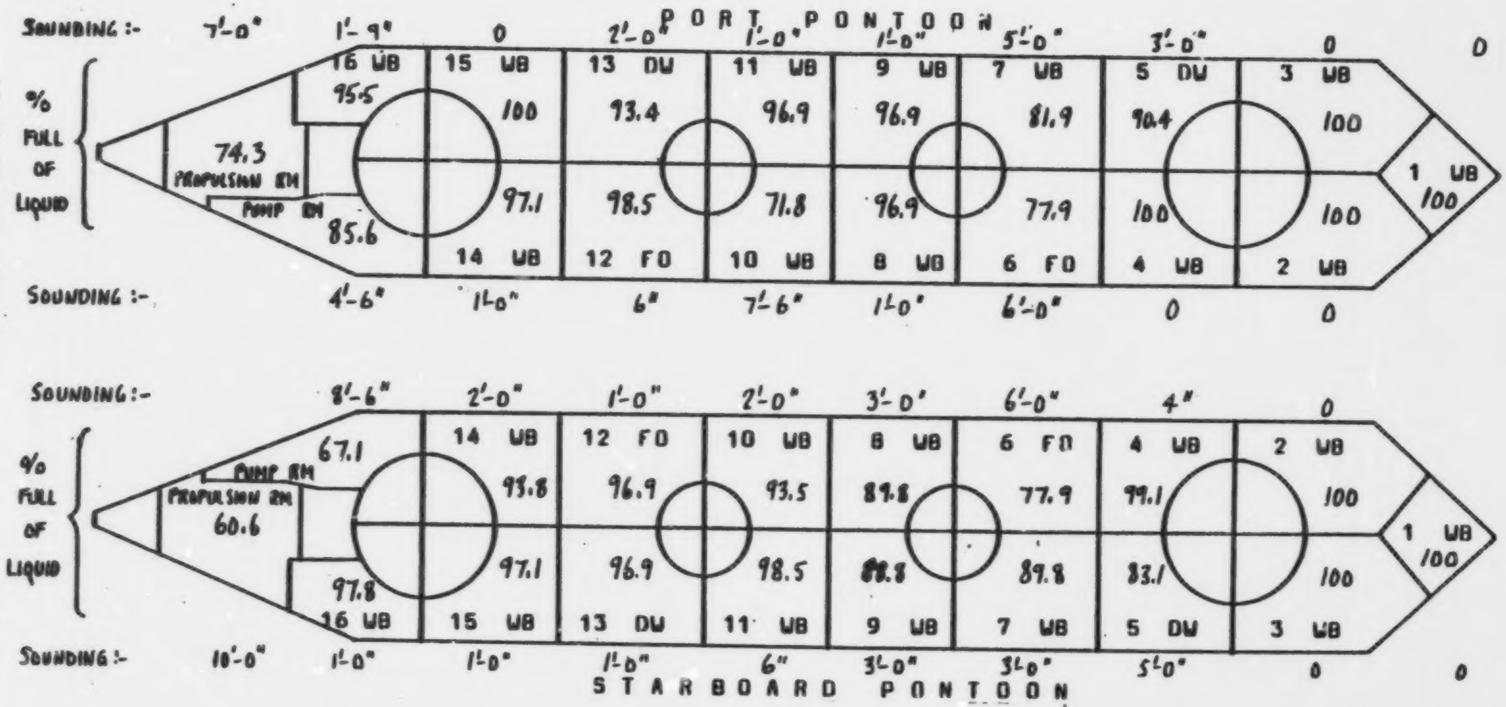
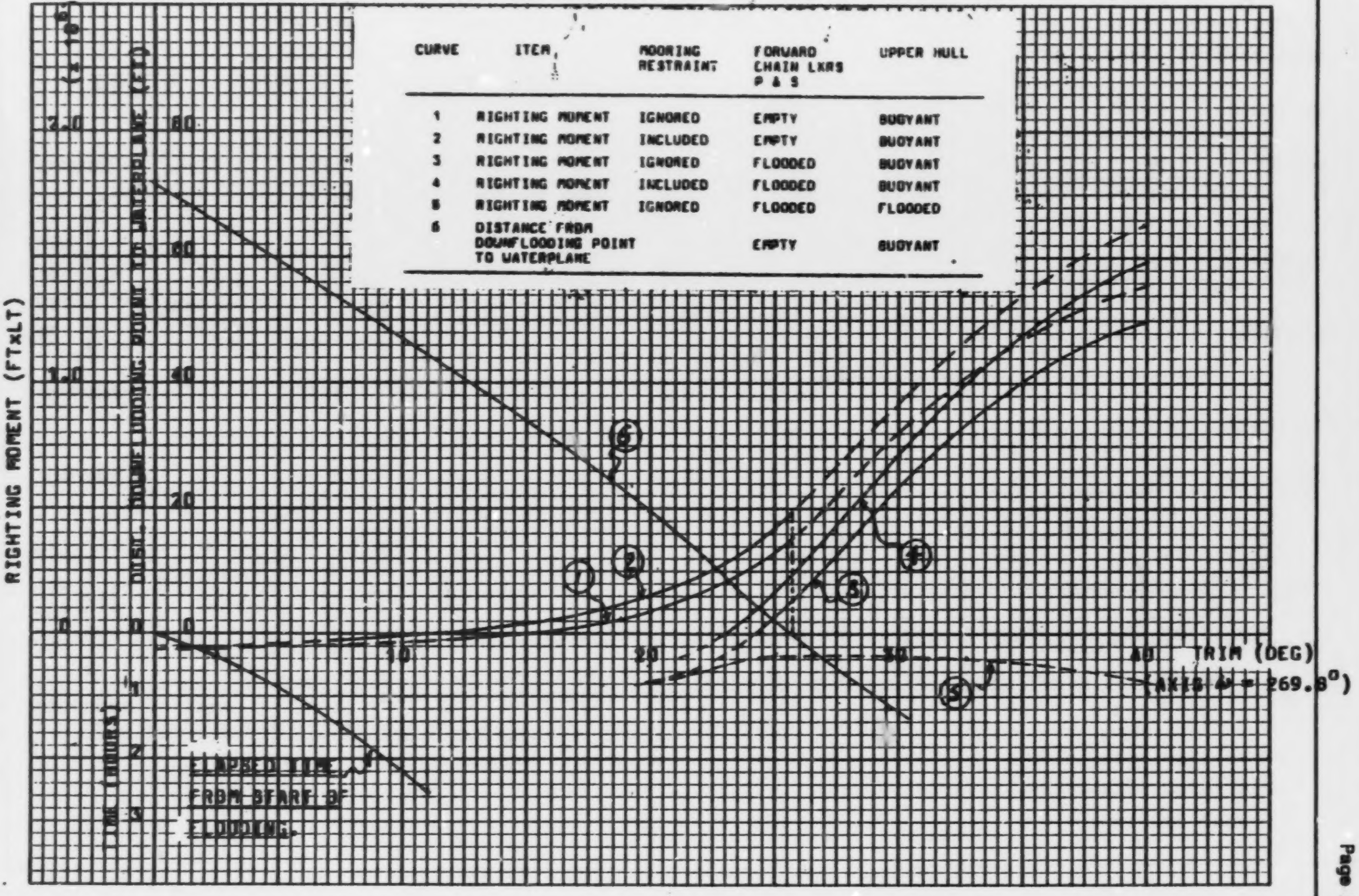

PORT PONTOON
SOUNDING :- 7'-0" 1'-9" 0 2'-0" 1'-0" 1'-0" 5'-0" 3'-0" 0 0
% FULL OF LIQUID
16 WB 95.5
74.3 PROPULSION RM
PUMP RM 85.6
15 WB 100
14 WB 97.1
13 DW 93.4
12 FO 98.5
11 WB 96.9
10 WB 71.8
9 WB 96.9
8 WB 96.9
7 WB 81.9
6 FO 77.9
5 DW 90.4
4 WB 100
3 WB 100
2 WB 100
1 WB 100
SOUNDING :- 4'-6" 1'-0" 6" 7'-6" 1'-0" 6'-0" 0 0
SOUNDING :- 8'-6" 2'-0" 1'-0" 2'-0" 3'-0" 6'-0" 4" 0
% FULL OF LIQUID
67.1
PUMP RM
PROPULSION RM 60.6
97.8 16 WB
14 WB 93.8
15 WB 97.1
12 FO 96.9
13 DW 96.9
10 WB 93.5
11 WB 98.5
8 WB 89.8
9 WB 89.8
6 FO 77.9
7 WB 89.8
4 WB 99.1
5 DW 83.1
2 WB 100
3 WB 100
1 WB 100
SOUNDING :- 10'-0" 1'-0" 1'-0" 1'-0" 6" 3'-0" 3'-0" 5'-0" 0 0
STARBOARD PONTOON

FIG. 7. RESULTS OF ACOUSTIC SOUNDINGS OF AIR POCKETS IN TANKS AND COMPARTMENTS OF LOWER HULLS, AND CORRESPONDING PERCENTAGE FILLING BY LIQUID.

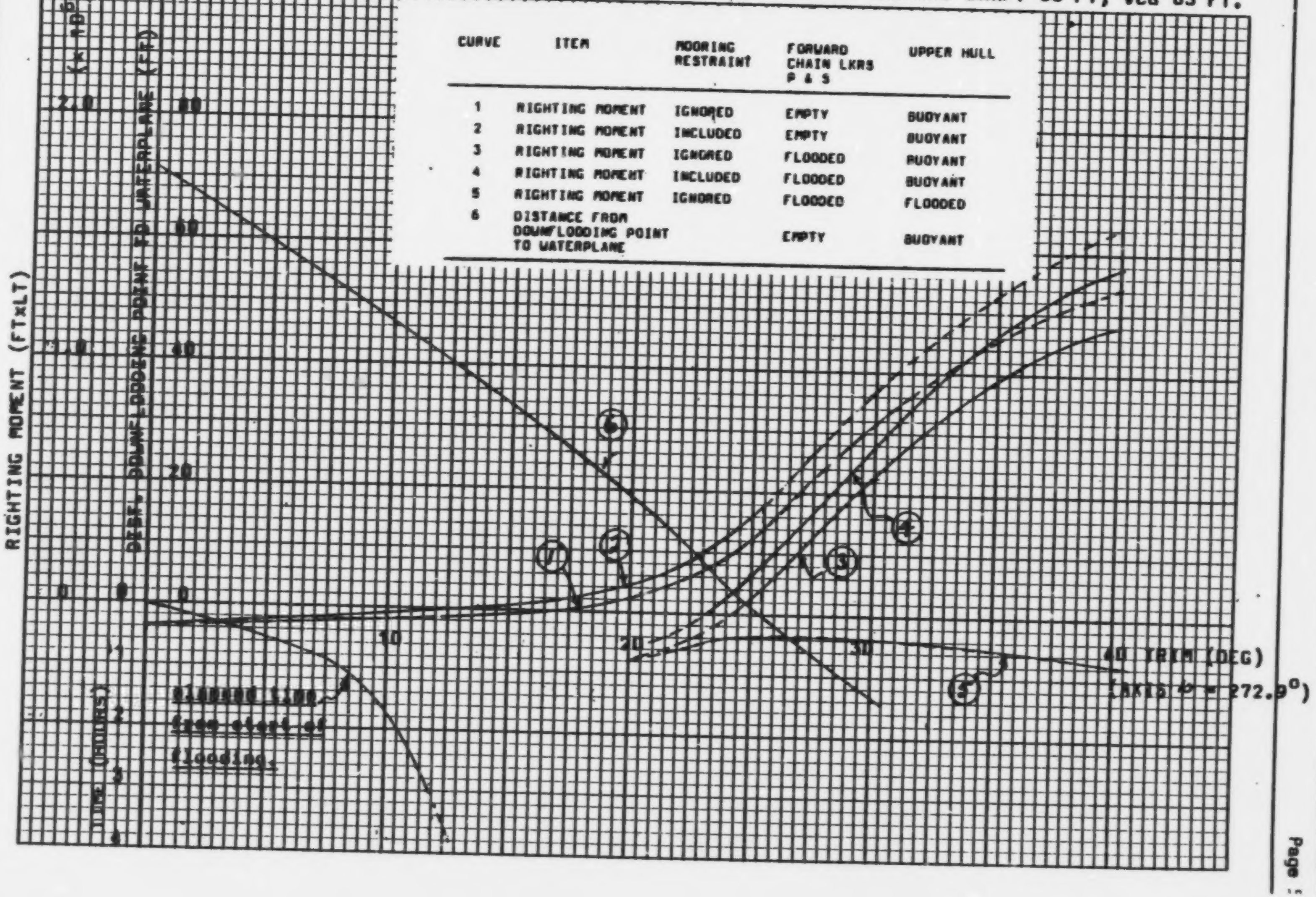
WB = water ballast tank
DW = drill water tank
FO = fuel oil tank

FIG 8 AFTER FLOODING FROM TANK PT 10 TO PT 4. ASSUMED INITIAL DRAFT 80 FT, VCG 63 FT.



CURVE	ITEM	MOORING RESTRAINT	FORWARD CHAIN LKRS P & S	UPPER HULL
1	RIGHTING MOMENT	IGNORED	EMPTY	BUOYANT
2	RIGHTING MOMENT	INCLUDED	EMPTY	BUOYANT
3	RIGHTING MOMENT	IGNORED	FLOODED	BUOYANT
4	RIGHTING MOMENT	INCLUDED	FLOODED	BUOYANT
5	RIGHTING MOMENT	IGNORED	FLOODED	FLOODED
6	DISTANCE FROM DOWNFLOODING POINT TO WATERPLANE		EMPTY	BUOYANT

FIG 9 AFTER FLOODING FROM TANK PT 10 TO PT 1. ASSUMED INITIAL DRAFT 80 FT, VCG 63 FT.



CURVE	ITEM	MOORING RESTRAINT	FORWARD CHAIN LKRS P & S	UPPER HULL
1	RIGHTING MOMENT	IGNORED	EMPTY	BUOYANT
2	RIGHTING MOMENT	INCLUDED	EMPTY	BUOYANT
3	RIGHTING MOMENT	IGNORED	FLOODED	BUOYANT
4	RIGHTING MOMENT	INCLUDED	FLOODED	BUOYANT
5	RIGHTING MOMENT	IGNORED	FLOODED	FLOODED
6	DISTANCE FROM DOWNFLOODING POINT TO WATERPLANE		EMPTY	BUOYANT

APPENDIX I

LIST OF DRAWINGS AND DOCUMENTS

DRAWING NO.	TITLE
G-0102 1/3A	GENERAL LINES
G-0102 2/3C	LINES BOW OF LOWER HULL
G-0102 3/3C	LINES STERN OF LOWER HULL
G-0103 1/8	GENERAL ARRANGEMENT STARBOARD ELEVATION
G-0103 2/8	GENERAL ARRANGEMENT FORWARD ELEVATION
G-0103 3/8	GENERAL ARRANGEMENT LOWER HULL EXTERIOR FITTING
G-0103 4/8	GENERAL ARRANGEMENT LOWER HULL INTERIOR FITTING
G-0103 5/8	GENERAL ARRANGEMENT LOWER DECK & MUD RETURN SYSTEM
G-0103 6/8	GENERAL ARRANGEMENT UPPER DECK & DRILL FLOOR
G-0103 7/8	GENERAL ARRANGEMENT QUARTERS
G-0103 8/8	GENERAL ARRANGEMENT FITTING & ACCESS IN COLUMN
G-1012	RESULTS OF INCLINING EXPERIMENT
G-1014A	RESULTS OF SEA TRIAL (BALLAST & DEBALLAST)
G-1014B	RESULTS OF SEA TRIAL (MOORING & CRUISING TEST)
G-1101A	DAMAGE CONTROL PLAN
G-1102	TANK CAPACITY PLAN
G-1104A	CURVES OF FORM
G-1105 1/5	CROSS CURVES OF STABILITY (LONG. AFT)
G-1105 2/5	CROSS CURVES OF STABILITY (LONG. FWD)
G-1105 3/5	CROSS CURVES OF STABILITY (TRANS.)
G-1105 4/5	CROSS CURVES OF STABILITY (DIAGONAL 37.2°)
G-1105 5/5	CROSS CURVES OF STABILITY (DIAGONAL 45°)
G-1106	WIND HEELING MOMENT CURVES
G-3161-1B	BALLAST, DRILL WATER & BILGE LOWER HULL SYSTEM
G-3161-2B	DRILL WATER SYSTEM
G-3161-3B	SALT WATER SERVICE SYSTEM
G-3161-4A	FUEL OIL FILL TRANSFER & SERVICE SYSTEM
G-3161-7A	AIR, SOUND & OVER FLOW SYSTEM
G-3161-9B	COMPRESSED AIR SYSTEM
G-3161-12A	CONTROL AIR SYSTEM
G-3161-15A	TANK LEVEL INDICATOR SYSTEM
H-4101B	LOWER HULL CONTRUCTION PROFILE
H-4102	COLUMN CONSTRUCTION PROFILE
H-4103A	HORIZONTAL BRACE CONSTRUCTION PROFILE
H-4104	VERTICAL TRUSS CONSTRUCTION PROFILE
H-5011	KORT RUDDER
H-5012 1/2D	ANCHOR BOLSTER (AFT PART)
H-5012 2/2A	ANCHOR BOLSTER (FWD.PART)

DRAWING NO.	TITLE
H-5113	BOAT BUMPER PC2B, PC3B, SC2B, SC3B
H-5115 1/2B	STABILITY CONES PC1C, SC1C (PROFILE)
H-5115 2/2B	STABILITY CONES PC1C, SC1C (PLAN)
F-4100 1/14B	ANCHOR HANDLING ARRANGEMENT (SC1,PC4 PLAN AT EL.151'-6")
F-4100 2/14	ANCHOR HANDLING ARRANGEMENT (SC1,PC4 PLAN AT EL 134'-0") 130'-0")
F-4100 3/14	ANCHOR HANDLING ARRANGEMENT (SC1,PC4 PLAN AT EL 96'-6") 88'-8")
F-4100 4/14	ANCHOR HANDLING ARRANGEMENT (SC1,PC4 PLAN AT EL 80'-0") 70'-0")
F-4100 5/14	ANCHOR HANDLING ARRANGEMENT (SC1,PC4 SECT. A-A)
F-4100 6/14	ANCHOR HANDLING ARRANGEMENT (SC1,PC4 SECT. B-B)
F-4100 7/14	ANCHOR HANDLING ARRANGEMENT (SC1,PC4 SECT. C-C)
F-4100 8/14B	ANCHOR HANDLING ARRANGEMENT (SC4,PC1 PLAN AT 151'-6")
F-4100 9/14	ANCHOR HANDLING ARRANGEMENT (SC4,PC1 PLAN AT 134'-0") 130'-0")
F-4100 10/14	ANCHOR HANDLING ARRANGEMENT (SC4,PC1 PLAN AT 96'-6") 88'-8")
F-4100 11/14	ANCHOR HANDLING ARRANGEMENT (SC4,PC1 PLAN AT EL 80'-0") 70'-0")
F-4100 12/14	ANCHOR HANDLING ARRANGEMENT (SC4,PC1.SECT. D-D)
F-4100 13/14	ANCHOR HANDLING ARRANGEMENT (SC4,PC1.SECT. E-E)
P-0401	MACHINERY ARRANGEMENT LOWER HULL PUMP ROOM
P-0402A	ARRANGEMENT OF "P" TANKS IN COLUMN
P-0403A	MACHINERY ARRANGEMENT BALLAST CONTROL ROOM
P-2027B	AIR PIPE HEAD 50A
P-3002	AIR PIPE HEAD BONNET TYPE
P-4101A	GENERAL PIPING PLAN IN LOWER HULL TANKS
P-4103B	GENERAL PIPING PLAN IN LOWER HULL PUMP ROOM
P-4104D	GENERAL PIPING PLAN IN KEEL COOLER (S.SIDE)

DRAWING NO.	TITLE
P-4106C	GENERAL PIPING PLAN IN PC1 LOWER PART (SC1 OPP.HAND)
P-4107B	GENERAL PIPING PLAN IN PC2 LOWER PART (SC2 OPP.HAND)
P-4108D	GENERAL PIPING PLAN IN PC3 LOWER PART (SC3 OPP.HAND)
P-4109A	GENERAL PIPING PLAN IN PC4 LOWER PART (SC4 OPP.HAND)
P-4111A	GENERAL PIPING PLAN IN SC1 UPPER PART
P-4113A	GENERAL PIPING PLAN IN SC2 UPPER PART
P-4115A	GENERAL PIPING PLAN IN SC3 UPPER PART
P-4116B	GENERAL PIPING PLAN IN LOWER HULL PUMP ROOM CONTROL & GAUGING PIPE
P-4118 1/2B	GENERAL PIPING PLAN IN SC4 UPPER PART
P-4118 2/2	GENERAL PIPING PLAN IN SC4 UPPER PART

Booklet of operating conditions.

Ocean Ranger emergency procedures by ODECO drilling of Canada Ltd.

General description of Ocean Ranger.

General description of Dyvi Delta.

Classification status of Zapata Ugland, Sedco 706 and Ocean Ranger, 17th February 1982 from A.B.S.

First draft sequence of events from B. Fowler 17th February 1982.

Report of sequence of events for Ocean Ranger by C. Noll 5th March 1982 for the Petroleum Directorate.

Report on the second investigation into the loss of the Ocean Ranger conducted by Mobil Oil using the vessels Balder Cabot and Polaris V by G.R. Cobb from 28th February to 3rd March 1982 for the Petroleum Directorate.

Stability data from rig for 25th January, 1st February and 9th of February 1982.

Telexed morning reports for 9th, 10th, 11th, 12th, 13th and 14th of February 1982.

U.S.C.G. Exhibit 43, Report on the stability of the M.O.D.U. Ocean Ranger, 27th May 1982.

Selection made by the Petroleum Directorate of the transcripts from the hearings of the enquiry held at Boston and New Orleans.

'OCEAN RANGER' INVESTIGATION

PART III

MOORING STUDY

OCEAN RANGER

MOORING STUDY

SUMMARY REPORT

OSG/DA/82048B

ORIGINAL ISSUE - SEPTEMBER 1982

ISSUE 'A' - DECEMBER 1982

RIG HEADING CHANGED FROM 336° TO AROUND 310° TRUE.

ENVIRONMENTAL LOADS RE-CALCULATED.

COMPUTER MOTION ANALYSIS RE-RUN.

ISSUE 'B' - MARCH 1983

Lloyd's Register of Shipping Offshore Services Group

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OCEAN RANGER
MOORING STUDY
SUMMARY REPORT

THIS REPORT SUMMARISES THE MAIN RESULTS AND CONCLUSIONS FROM THE SOCIETY'S STUDY OF OCEAN RANGER'S MOORING SYSTEM AT THE TIME OF THE ACCIDENT.

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1 INTRODUCTION

1.1 General

1.1.1 This study of Ocean Ranger's mooring system concentrates on the specific conditions which existed - where these are known - at around the time of the accident on 15th February, 1982.

1.1.2 A certain number of assumptions had to be made where specific data was not available or obtainable. These assumptions will be identified as such in the detailed text of this report.

1.1.3 Data has been presented in U.S./Imperial units of kips, feet and knots so that convenient cross-reference can be made if required to the original Ocean Ranger mooring system design data.

1.2 Location of Ocean Ranger

1.2.1 The location of Ocean Ranger at time of accident was:

Latitude	46° 43' 33"	NORTH
Longitude	48° 50' 13"	WEST

1.2.2 The water depth at this location was taken for analysis purposes as 79m (259').
(From Polaris V Survey of 20th February, 1982.

1.3 Environmental Conditions

1.3.1 The following cases (Table 1.1) were selected to represent, in mooring terms, the worst environmental conditions to occur at around the time of the accident.

TABLE 1.1

CASE	WIND			WAVES					CURRENT	
	SPEED (KNOTS)			WIND DRIVEN		SWELL				
	RECORDED V_R	EFFECTIVE V_{10}	DIRECTION (°TRUE)	SIGNIFICANT HEIGHT (FT)	PERIOD (SECS)	SIGNIFICANT HEIGHT (FT)	PERIOD (SECS)	DIRECTION (°TRUE)	SPEED (KNOTS)	DIRECTION (°TRUE)
1	72	56	240°	33	12	-	-	-	0.5	240°
2	58	45	270°	33	11	23	9	230°	0.5	270°

TABLE 1.1 NOTES

1) Recorded wind speeds given in Table 1.1 were obtained from wind sensor on Ocean Ranger positioned 79m above mean sea level. These recorded wind speeds have been transformed for calculation purposes to an equivalent effective wind speed at 10m above mean sea level, thus:

$$V_{10} = V_R \cdot \left(\frac{H}{10}\right)^{-0.12}$$

Where, V_{10} = Wind speed at 10 m above mean sea level

V_R = Wind speed recorded at Hms above sea level

2) Current velocity at the time of the accident is not known. Neither Ocean Ranger, Sedco 706 or Zapata Ugland logged current data. It is however understood that current speeds in the area concerned are not high and that 0.5 knot is an appropriate velocity for analysis purposes.

Current direction was taken to be co-linear with wind.

1.4 Mooring Pattern

1.4.1 The mooring spread shown in Fig. 1.1 is based on sketch titled:-

"Odeco Ocean Ranger Hibernia J-34 Anchor Pattern."

Fig. 1.1

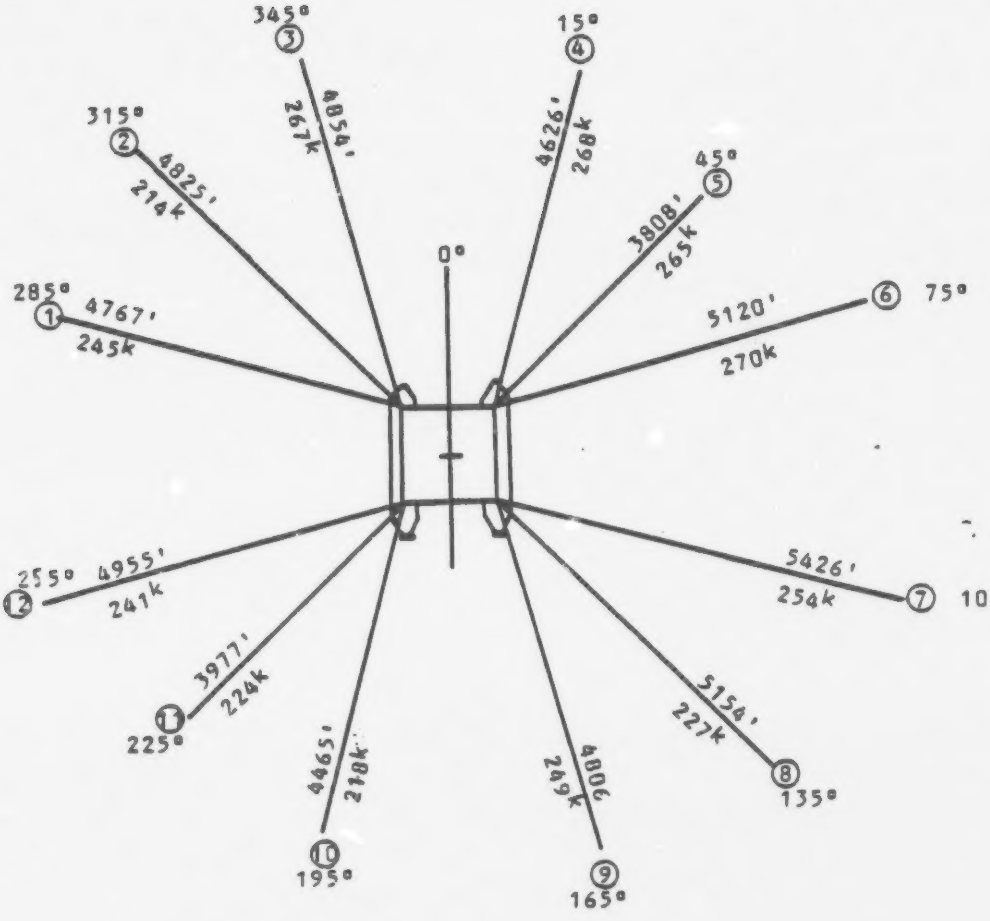

0°
285° ① 4767' 245k
315° ② 4825' 214k
345° ③ 6854' 267k
15° ④ 4626' 268k
45° ⑤ 3808' 265k
⑥ 75° 5120' 270k
⑦ 105° 5426' 254k
⑧ 135° 5154' 227k
⑨ 165° 4006 269k
⑩ 195° 4465' 218k
⑪ 225° 3977' 224k
⑫ 255° 4955' 241k

FIG 1.1 NOTES

1) Line lengths have been taken as total line out to anchor, measured from lower fairleader.

2) Tensions are taken as in-line tension values.

3) Angles of mooring lines relative to rig heading were not given in the anchor pattern sketch but are assumed to have been close to the pattern required by the Operations Manual. i.e. 15°, 45°, 75° etc.

Consideration was given to defining the mooring spread geometry from the anchor buoy positions reported by Polaris V at survey on 19th February, 1982. However, in view of the possible deviation between observed buoy position and actual anchor location (due to pendant lengths) it was considered preferable to use the standard 15°, 45°, 75° array. In any case the differences between standard and actual spreads, which might have existed, would not significantly affect the analysis results.

2 LOADS AND FORCES

2.1 Wind Force

2.1.1 Wind forces were calculated from the following:-

$$F_W = 0.00338\ V^2\ A\ C_H C_S \times 10^{-3}\ \text{kips}$$

Where, V = Effective 1 minute mean wind velocity (knots)

A = Projected area of structure or structural element (ft.^{2})

C_H = Height coefficient (See Table 2.1)

C_S = Shape coefficient (See Table 2.2)

TABLE 2.1

HEIGHT ABOVE MEAN SEA LEVEL IN m (ft)	C_H
0-15 (0-50)	1,0
15-30 (50-100)	1,1
30-45 (100-150)	1,2
45-60 (150-200)	1,3
60-75 (200-250)	1,4

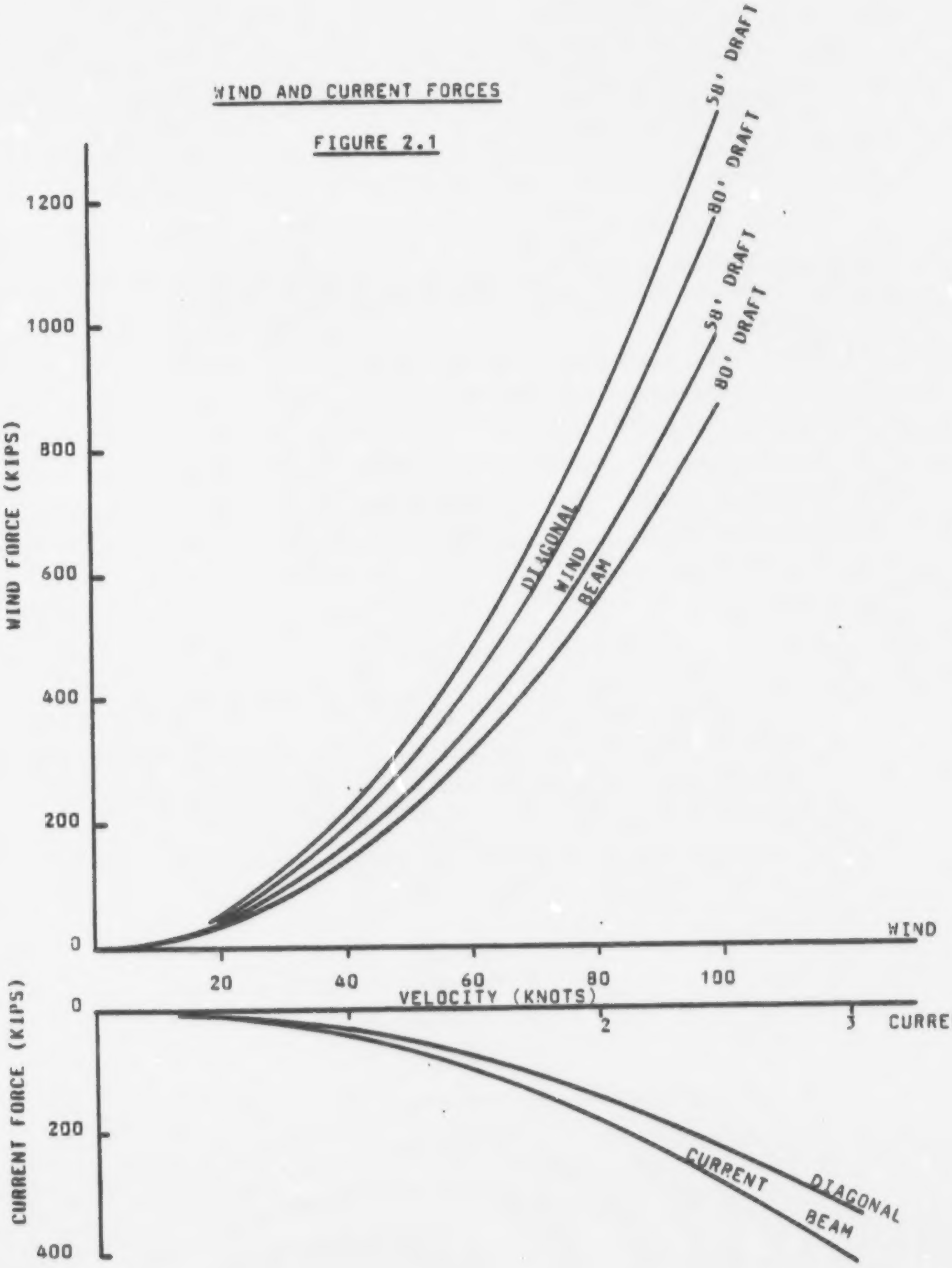
TABLE 2.2

SHAPE	C_S
Cylindrical	0,5
Large flat surface (hull, deckhouse, smooth under deck areas)	1,0
Drilling Derrick	1,25
Exposed beams and girders under deck	1,3
Isolated shapes (crane, beams etc.)	1,5

2.1,2 Wind forces calculated for beam and diagonal directions plotted against wind speed are given in Fig. 2.1

WIND AND CURRENT FORCES

FIGURE 2.1



2.2 Current Force

2.2.1 Current force on semi-submersible hulls and columns is largely generated by drag resistance. Frictional resistance is not significant and has been neglected in this case.

$$F_c = \tfrac{1}{2} \rho A \, C_D \, V^2$$

Where,
F_c = Current drag resistance (lbs)
ρ = Mass density of water
A = Projected area of underwater hull or structural element (ft.^{2})
C_D = Drag coefficient
V = Current velocity (ft./sec)

2.2.2 Plots of current force against velocity are given in Fig. 2.1 for beam and diagonal cases.

2.3 Wave Drift

2.3.1 Steady wave drift forces have been calculated from:

$$F_D = C_{MD} \cdot \sum D^2 \left(\frac{H_{1/3}}{T_S}\right)^2$$

Where,
F_D = Mean drift force (lbs)
C_{MD} = Mean drift force coefficient
= 2.28 lbs.sec.^{2}/ft.^{4}
D = Column diameter (feet)
$H_{1/3}$ = Significant wave height (feet)
T_S = Wave period (seconds)

2.3.2 Wave drift forces were calculated for each of the specific waves selected for Cases 1 and 2 (See 1.3.1/ Table 1.1) with the following results:-

TABLE 2.3

ENVIRONMENTAL CASE	SIGNIFICANT WAVE		MEAN DRIFT FORCE (KIPS)
	HEIGHT (FEET)	PERIOD (SECS.)	
1	33	12	98
2	33	11	116
2	23	9	60

2.4 Wave Displacement

2.4.1 First order wave effects - surge and sway - are particularly significant in shallow water moorings. This is due to the stiffness characteristics or slope of the load - displacement curve of the catenary in shallower water depths, where comparatively small horizontal displacements generate large increases in tension.

2.4.2 Wave energy and rig response spectra were produced for each relevant case - wind driven, swell and combined waves.

The response amplitude operators used to establish the response spectra were taken from data sheet titled:

"R.A.O. (Horizontal Displacement/Wave Height vs.) Wave Period for Bow, Diagonal and Beam for Ocean Ranger."

2.4.3 Calculated motion amplitudes (± values from displaced mean position) are given in Table 2.4.

TABLE 2.4

ENVIRONMENTAL CASE	SIGNIFICANT WAVE		SURGE (FT)		SWAY (FT)		QUARTERING (FT)	
	HEIGHT (FEET)	PERIOD (SECS)	SIGNFCT	MAXM	SIGNFCT	MAXM	SIGNFCT	MAXM
1	33'	12	5.0	8.6	4.4	7.5	5.1	8.7
2	33	11	4.5	7.5	3.9	6.7	4.5	7.6
	23	9	2.0	3.4	2.1	3.6	1.9	3.3
	40	-	4.9	8.3	4.5	7.6	4.9	8.3

Note :-

1. Maximum displacements are based on $\frac{H_{MAX.}}{H_{\frac{1}{3}}} = 1.7$ (the ratio observed at Ocean Ranger location on 15th February).

2.5 Combined Loads

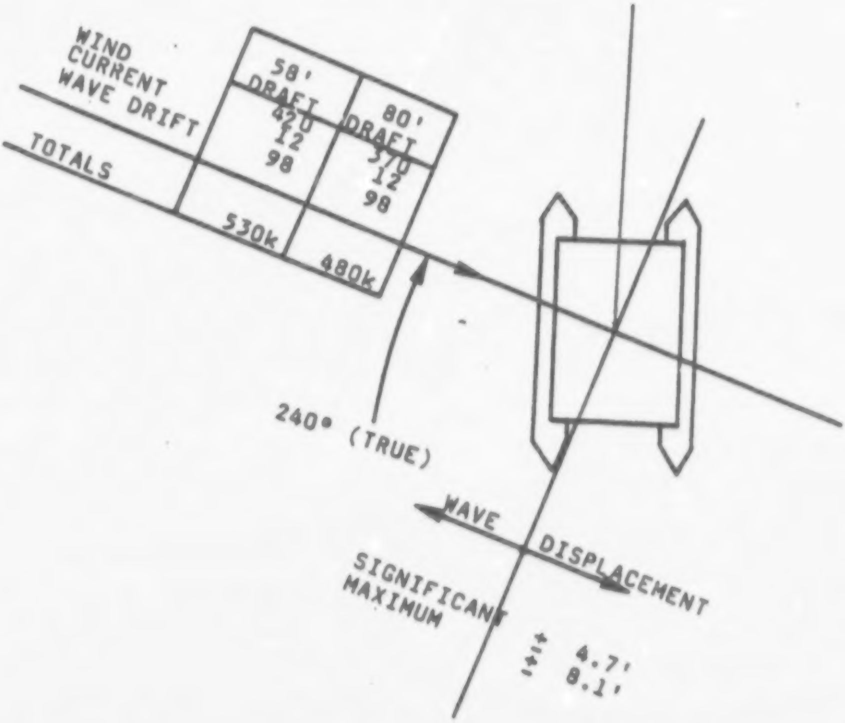
LOAD CASE 1

Environmental Conditions

Wind (Speed/Direction)	56 Knots/240°
Wave (H_S/T_S/Direction)	33'/12 secs./240°
Current (Speed/Direction)	0.5 Knot/240°

Summary of Calculated Loads and Displacement

Fig. 2.2


WIND
CURRENT
WAVE DRIFT
TOTALS
58' DRAFT
420
12
98
530k
80' DRAFT
370
12
98
480k
240° (TRUE)
WAVE DISPLACEMENT
SIGNIFICANT
MAXIMUM
± 4.7'
± 8.1'

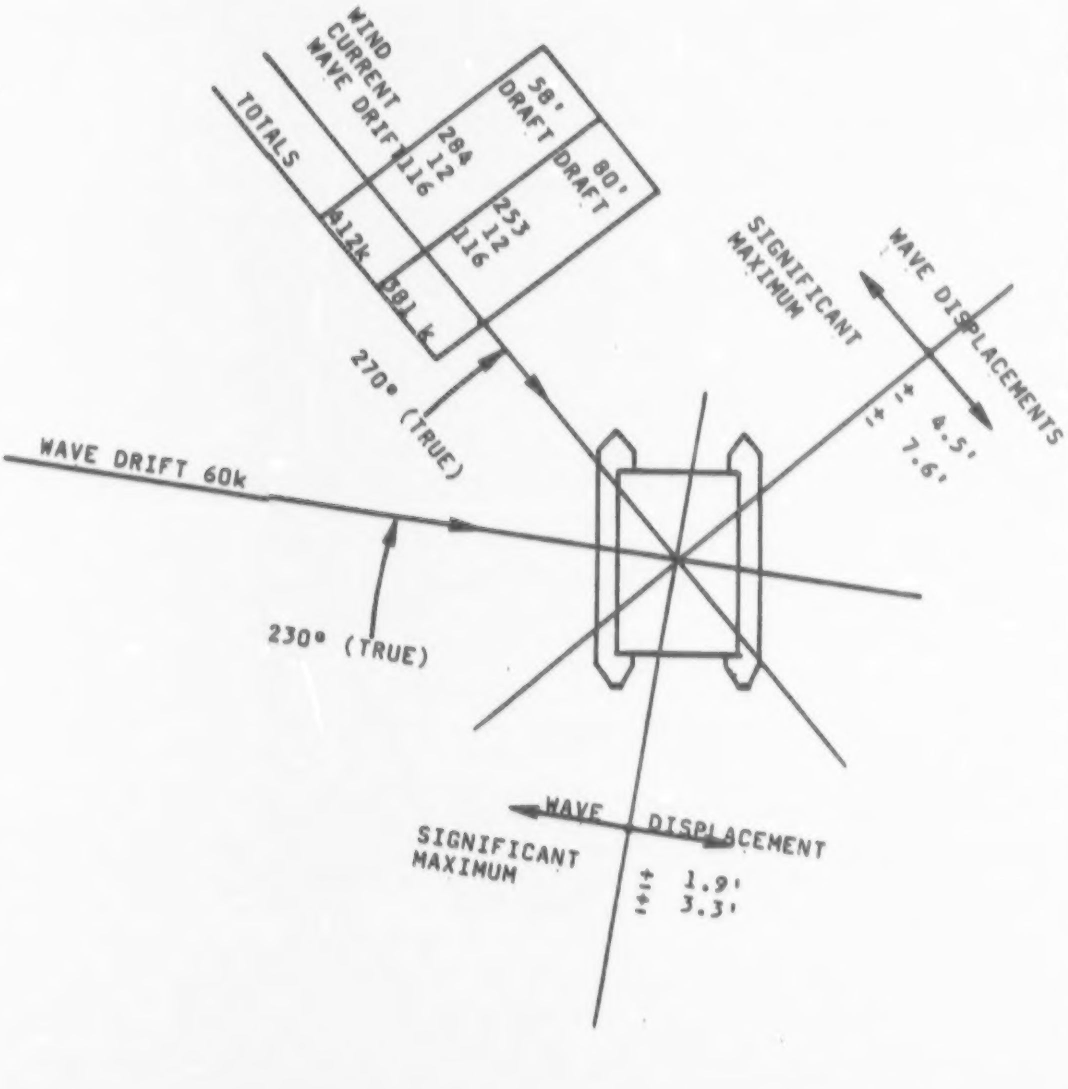
LOAD CASE 2

Environmental Conditions

Wind (Speed/Direction	45 Knots/270°
Wave-wind driven (H_S/T_S/ Direction)	33'/11 secs./270°
Wave-swell (H_S/T_S/Direction)	23'/9 secs./230°
Current (Speed/Direction)	0.5 Knots/270°

Summary of Calculation Loads and Displacement

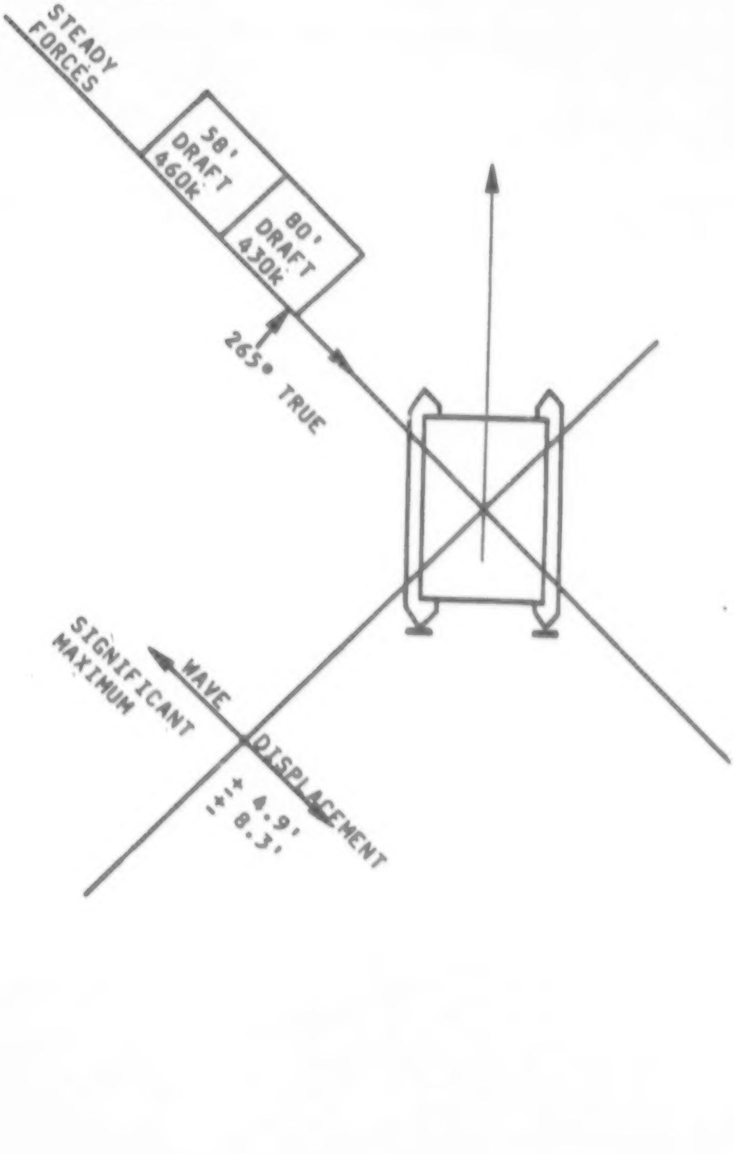
Fig. 2.3


WIND
CURRENT
WAVE DRIF
TOTALS
58' DRAFT
284
12
116
412k
80' DRAFT
253
12
116
381 k
270° (TRUE)
WAVE DRIFT 60k
230° (TRUE)
SIGNIFICANT
MAXIMUM
WAVE DISPLACEMENTS
± 4.5'
± 7.6'
WAVE DISPLACEMENT
SIGNIFICANT
MAXIMUM
± 1.9'
± 3.3'

LOAD CASE 2   CONTD.

Summary of Resultant Loads and Displacements

Fig. 2.4


STEADY FORCES
58' DRAFT 460k
80' DRAFT 430k
265° TRUE
SIGNIFICANT
MAXIMUM
WAVE
DISPLACEMENT
± 4.9'
± 8.3'

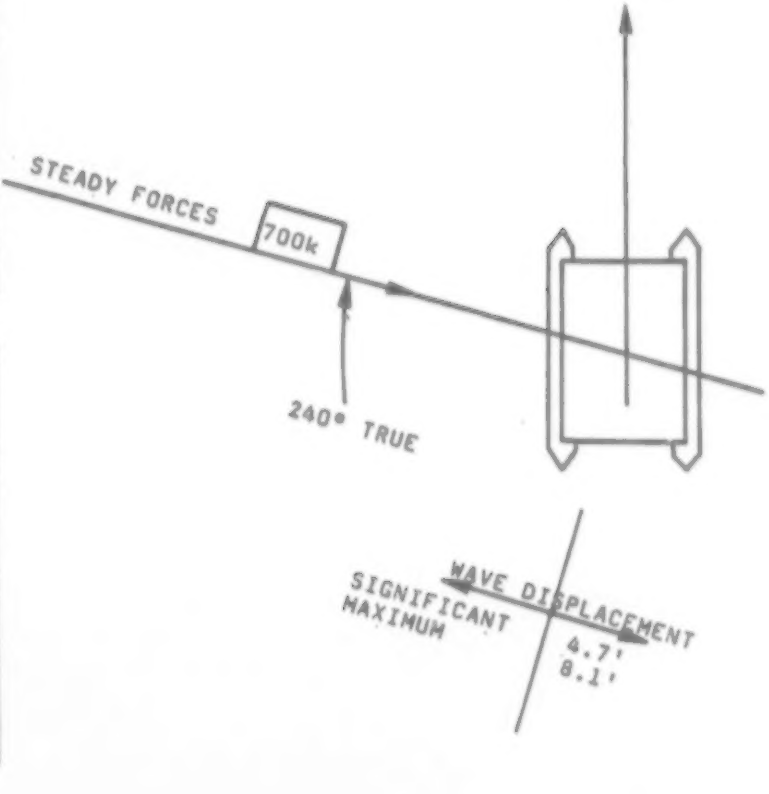
LOAD CASE 3

Environmental Conditions

Wind (Speed/Direction)	45 Knots/270°
Wave-wind driven (H_S/T_S/Direction)	33'/11 secs/270°
Wave-swell (H_S/T_S/Direction)	23'/9 secs/230°
Current (Speed/Direction)	0.5 Knots/270°

Summary of Resultant Loads and Displacements

Fig. 2.5


STEADY FORCES
700k
240° TRUE
WAVE DISPLACEMENT
SIGNIFICANT
MAXIMUM
4.7'
8.1'

SECTION 3 - COMPUTER ANALYSIS

3.1 Method of Analysis

3.1.1 A static mooring analysis was carried out using Lloyds Register program MSPRD.
Sample computer output is given in Appendix A.

3.1.2 It is standard operational practice offshore to slacken leeward mooring lines in severe weather conditions to relieve tensions on weather-side mooring lines. There is no specific evidence that any line adjustment was carried out on Ocean Ranger during the time leading up to the accident, therefore this procedure has not been simulated in the computer analysis.

3.2 Mooring System Characteristics

3.2.1 The combination chain-wire mooring system used by Ocean Ranger was as shown in Fig. 3.1 below.

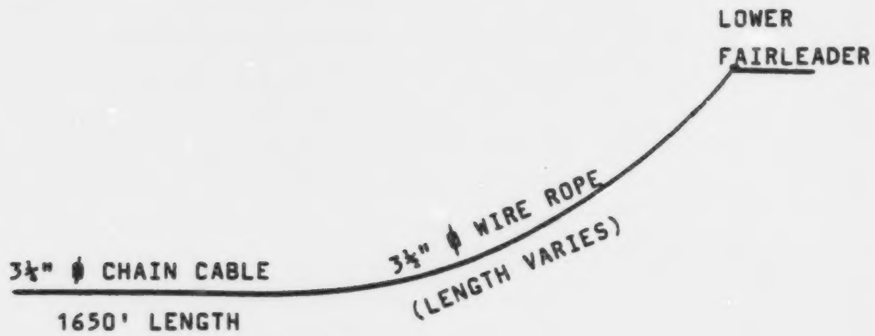

LOWER FAIRLEADER
3½" ϕ WIRE ROPE
(LENGTH VARIES)
3¼" ϕ CHAIN CABLE
1650' LENGTH

Fig. 3.1

NOTE

Total line lengths used in the analysis are as shown in Fig. 1.1.

3.2.2 The mooring line properties used were as follows:-

TABLE 3.1

PROPERTY	CHAIN CABLE	WIRE ROPE
Diameter (INCHES)	3.25	3.5
Area (FT.^{2})	0.0576	0.0668
Elastic Modulus (KIPS/FT.^{2})	2110000.0	1434000.0
Weight in Water (KIPS/FT.)	0.0907	0.0192
Breaking Strength (KIPS)	1210.0	1210.0

NOTES TABLE 3.1

1) Chain cable area is the cross-sectional area of one "bar."
Wire rope area is the complete nominal area enclosed by the rope diameter.

2) The modulus of elasticity is a notional value related to the cross-sectional areas defined in Note 1.

3.3 Cases.

3.3.1 The following cases were considered.

CASE	LOAD CASE	DRAFT/HEEL	NUMBER OF MOORING LINES
A	1	80' LEVEL	12
B	2	80' LEVEL	12
C	3	15° TO PORT	12
D	3	15° TO PORT	11

Table 3.2

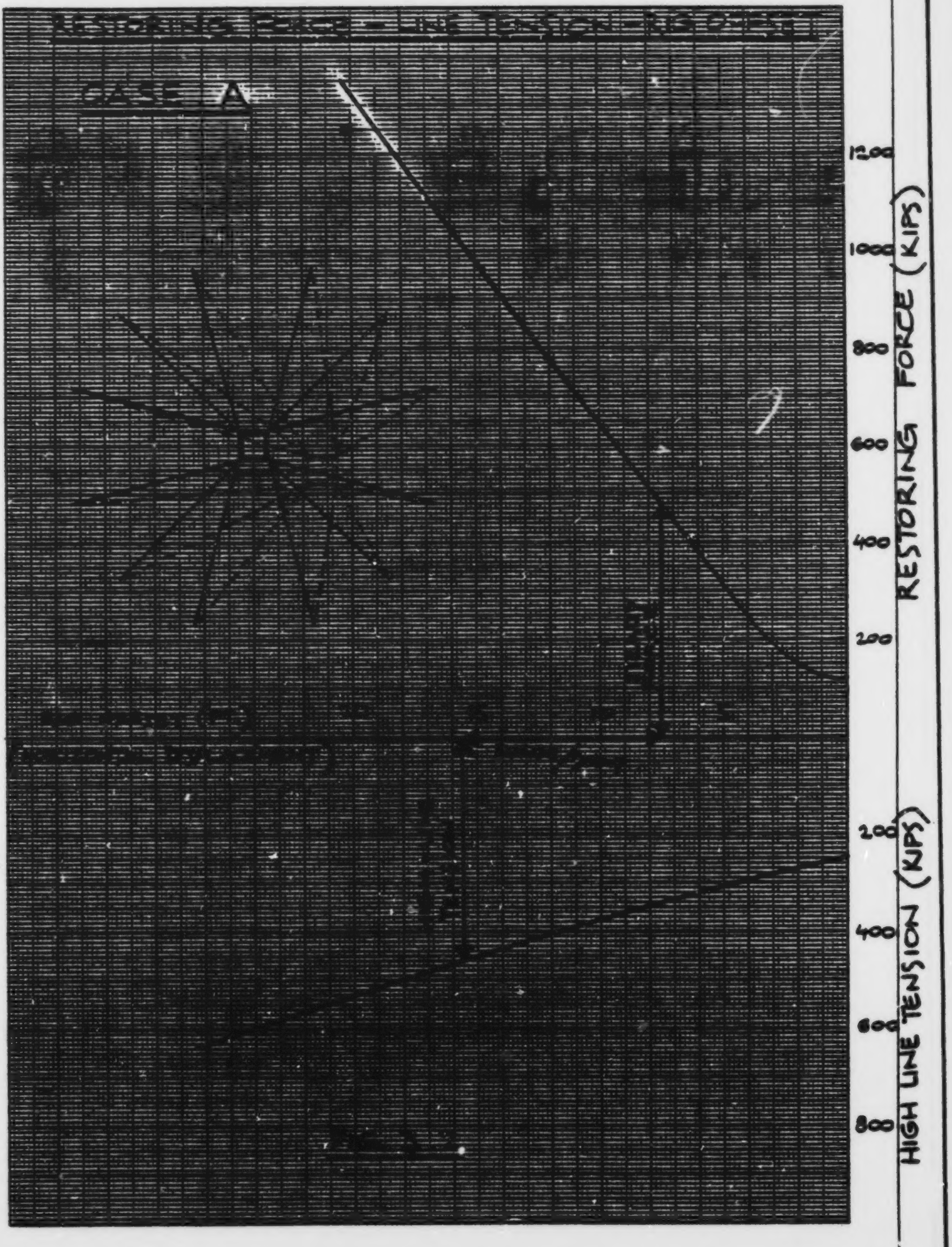
Notes

1 From initial runs load Case 1 was seen to give higher line tensions than ~~load~~ Case 2.

2 Case C was included to assess in approximate terms the effect on line tensions of the rig's reported 15° heel to port.

3 Case D was introduced to indicate whether the removal of the most highly loaded of the lines reported broken by Balder Cabot, might have led to progressive overloading and breakage of the others.

3.3 Results.


RESTORING FORCE – LINE TENSION – RIG OFFSET
CASE A
1200
1000
800
600
400
200
RESTORING FORCE (KIPS)
200
400
600
800
HIGH LINE TENSION (KIPS)

CASE A

LINE TENSIONS AT MAXIMUM RIG OFFSET

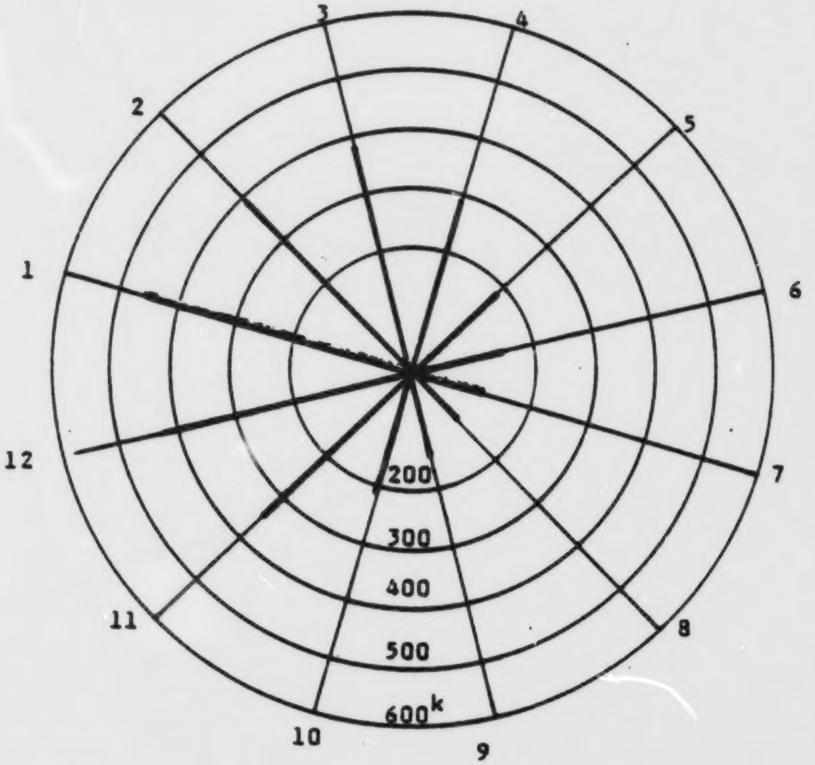
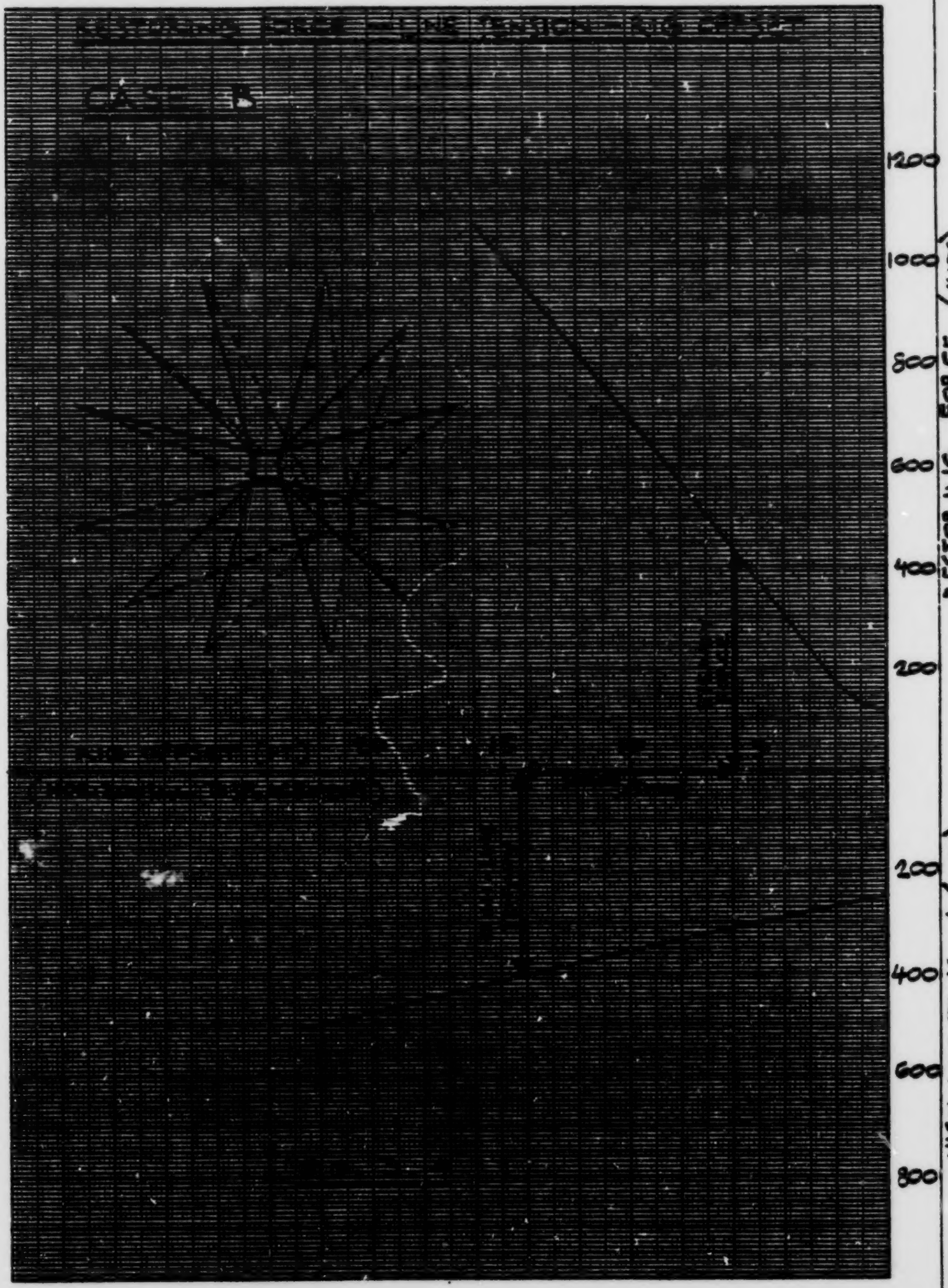


FIG.3.3


RESTORING FORCE & LINE TENSION – RIG OFFSET
CASE B
1200
1000
800
600
400
200
RESTORING FORCE (KIPS)
200
400
600
800
HIGH-LINE TENSION (KIPS)

CASE B

LINE TENSIONS AT MAXIMUM RIG OFFSET

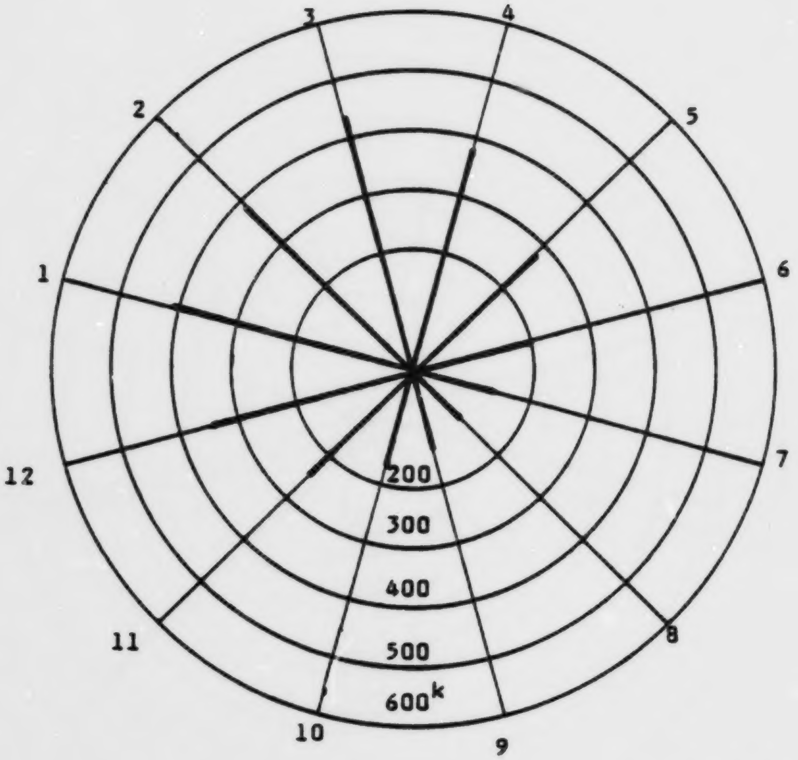


FIG.3.5

CASE C

LINE TENSIONS AT MAXIMUM RIG OFFSET

(15° HEEL TO PORT)

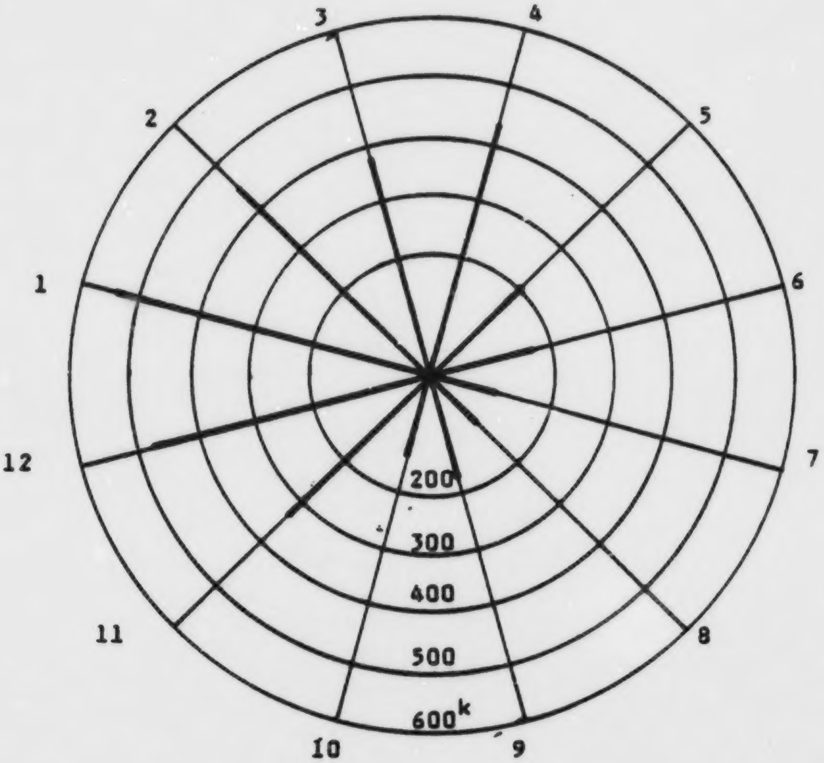


FIG 3.6.

CASE D

LINE TENSIONS AT MAXIMUM RIG OFFSET

(NO. 1 LINE REMOVED)

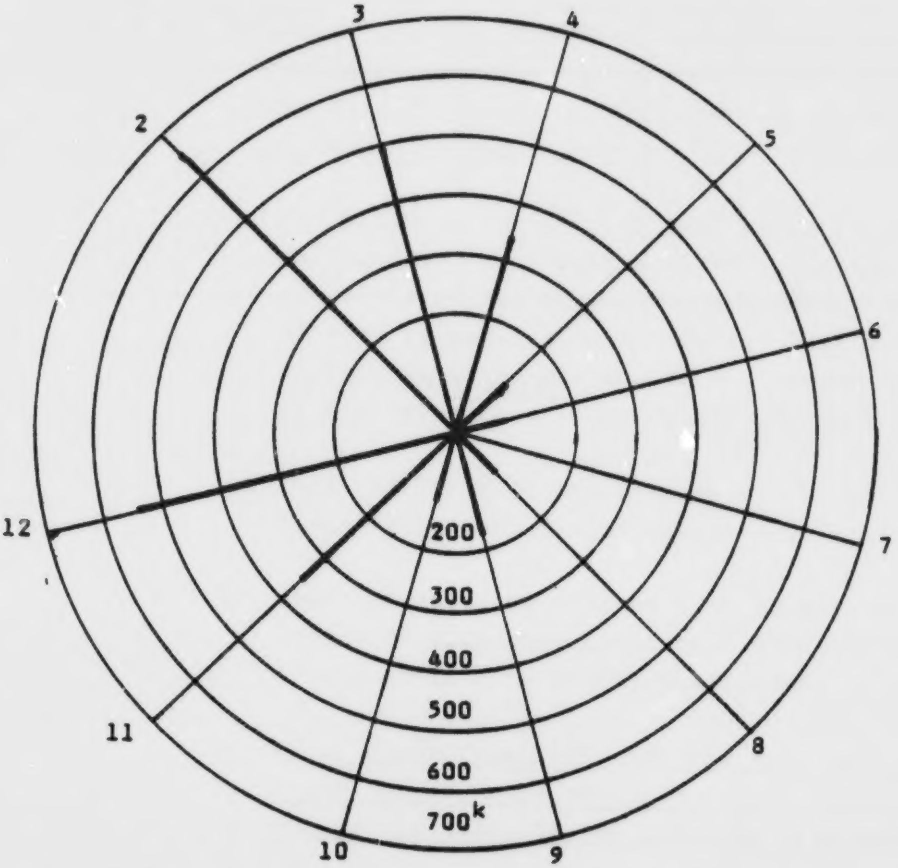


FIG. 3.7

SUMMARY OF MAXIMUM LINE TENSIONS

CASE *	HIGHEST LOADED MOORING LINE			NEXT HIGHEST LOADED MOORING LINE		
	LINE NO.	MAXIMUM TENSION (KIPS)	% AGE BREAKING STRENGTH	LINE NO.	MAXIMUM TENSION (KIPS)	% AGE BREAKING STRENGTH
A	1	460	38	12	420	35
B	3	435	36	I	406	34
C	1	535	44	12	473	39
D	2	650	54	12	540	45

Table 3.3

SECTION 4 Conclusions.

4.1 Mooring Lines.

4.1.1 The results given in 3.4 concentrate mainly on maximum line tensions, as these are the most fundamental and useful indicator of a system's integrity and reserve of strength.

4.1.2 There are few regulatory authorities who lay down specific requirements with respect to factors of safety etc. for positional mooring systems.

The standard for mooring line strength generally followed in the industry gives a minimum factor of safety of 2.0 against line breakage in extreme or survival conditions. That is, maximum line tension should not exceed 50% of the rated breaking strength of the line.

This factor of safety relates to conventional quasi-static methods of analysis.

4.1.3 Case 'C' gave the maximum line tension in the intact 12 line configuration - 535 kips or 44% of the basic line breaking strength.

We conclude from this that the mooring lines on Ocean Ranger would not have failed operationally due to overload, in the reported conditions.

4.1.4 Case 'D' was a hypothetical case carried out to estimate the probable consequence of removing the most highly loaded of the wires reported broken at survey i.e. line numbers 1,2,4 and 5.

The removal of line number 1 increased the tension in line number 2 to 650 kips or 54% of its breaking strength, but decreased the tensions in line numbers 4 and 5 due to re-distribution of load in yaw.

We conclude from this that line numbers 1,2,4 and 5 would not have failed progressively due to overload.

4.1.5 The criteria by which these conclusions have been reached relates only to failure by overload. Any of the other potential causes of failure such as axial or bending fatigue or corrosion wastage is outwith the scope of this study. ?

The reserve strength of individual mooring lines was calculated assuming that the actual ropes, chain cables and associated components were in satisfactory condition, with breaking strengths equal to or close to their original rated values.

References

1. Environment -
   Exhibit 14
   National Transportation Safety Board
   April 7th 1982
   Meteorological Factual Report
   Sinking of the Drilling Rig Ocean Ranger

2. Environment -
   Precis of some of the most important aspects of the environmental observations leading up to the disappearance of the drill rig Ocean Ranger.

3. Mooring Pattern -
   Ocean Ranger Mooring Pattern
   (un-numbered sketch)

4. Mooring Pattern -
   Ocean Ranger
   Hibernia J34
   Anchor Pattern
   (un-numbered sketch)

5. Report on the initial investigation into the loss of the Ocean Ranger conducted by Mobil Oil using the vessels Balder Cabot and Polaris V. February 19th to February 23rd 1982.

6. Report on the second investigation into the loss of the Ocean Ranger conducted by Mobil Oil using the vessels Balder Cabot and Polaris V. February 28th to March 3rd 1982.

7. Mooring System -
Odeco Operating Manual Section M

8. Response Amplitude Operators -
R A O (horizontal displacement/wave height) vs. wave period for bow, diagonal and beam for Ocean Ranger.

9. General Arrangement -
Drawing No. 28-711-01 sheet 1

10. General Arrangement - Starboard Elevation
Drawing No. G 0103 $1/_8$

11. General Arrangement - Forward Elevation
Drawing No. G 0103 $2/_8$

12. Wind Heeling Moment Curves
Drawing No. G 1106

13. Lloyds Register's Rules for the Construction and Classification of Mobile Offshore Units 1972.

14. Sea Spectra -
Paper-Society of Naval Architects and Marine Engineers April 1967 meeting.

15. Semi-submersible and tethered buoyant platforms. Some design considerations. Glasgow University Publications 1977.

APPENDIX A

LLOYD'S REGISTER OF SHIPPING

OCEAN ENGINEERING DEPARTMENT

STATIC CATENARY MOORING LINE ANALYSIS

DESIGNER :

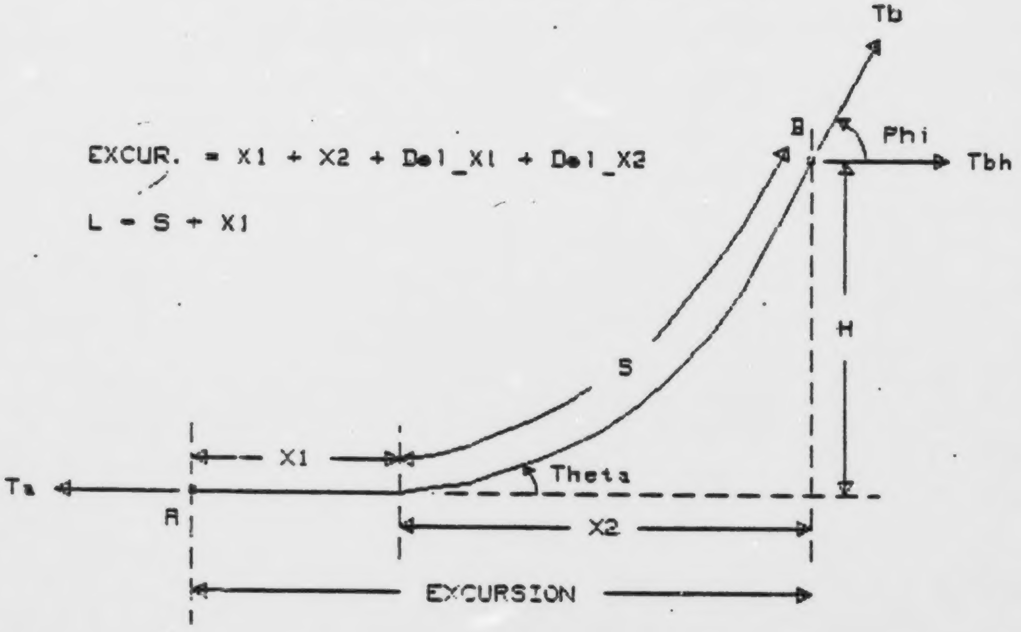
TITLE :

DATE : SURVEYOR :

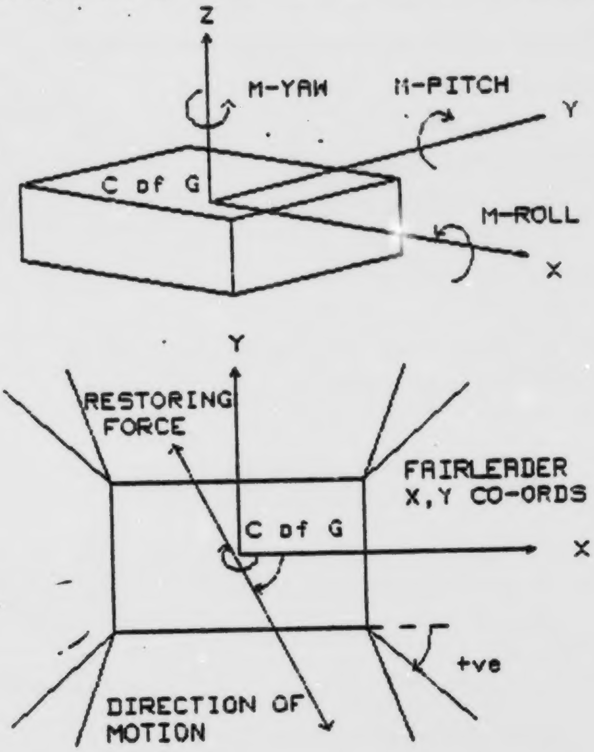
CATENARY GEOMETRY

EXCUR. = X1 + X2 + Del_X1 + Del_X2

L = S + X1


Tb
B
Phi
Tbh
H
S
X1
Theta
Ta
A
X2
EXCURSION

CO-ORDINATE SYSTEM + SIGN CONVENTION


Z
M-YAW
M-PITCH
Y
C of G
M-ROLL
X
Y
RESTORING FORCE
FAIRLEADER X,Y CO-ORDS
C of G
X
+ve
DIRECTION OF MOTION

ALL ANGLES - - +ve CLOCKWISE FROM X-AXIS

```
UNIT OF LENGTH IN :- FEET

UNIT OF FORCE AND WEIGHT IN :- KIPS



TOTAL LINE LENGTH ,L = 4767 FEET

ATTACHMENT POINT HEIGHT ,H = 275 FEET

LINE BREAKING STRENGTH = 1210 KIPS



INITIAL MOORING LINE CONFIGURATION

VESSEL C. of G.  X =    0.0  Y =    0.0   Z = 210.0

LINE   Tbh       X        Y        H     ALPHA       L          EA           Wc

  1   240.0    92.0     92.0    275.0    285.0    3117.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  2   209.0    92.0     92.0    275.0    315.0    3175.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  3   262.0    92.0     92.0    275.0    345.0    3204.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  4   263.0    92.0    -92.0    275.0     15.0    2976.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  5   260.0    92.0    -92.0    275.0     45.0    2158.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  6   265.0    92.0    -92.0    275.0     75.0    3470.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  7   249.0   -92.0    -92.0    275.0    105.0    3776.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  8   222.0   -92.0    -92.0    275.0    135.0    3504.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
  9   244.0   -92.0    -92.0    275.0    165.0    3156.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
 10   213.0   -92.0     92.0    275.0    195.0    2615.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
 11   219.0   -92.0     92.0    275.0    225.0    2327.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07000E-
 12   236.0   -92.0     92.0    275.0    255.0    3305.0  9.57912E+04  1.92000E-
                                                  1650.0  1.21536E+05  9.07060E-
```

```
--------------------------------------------------------------------------------
|
|        NOTICE : POSITIVE ANGLE MEASURED IN CLOCKWISE DIRECTION
|
|                          STATIC  CONDITIONS
|
|    RESTORING FORCE =  1.21787E+02  AT  42.5 DEGREES FROM  GLOBAL X - AXIS
|    ========================================================================
|
|   M - ROLL =                 M - PITCH =                 M - YAW =
|
|        ROTATION OF BODY =    .10 DEGREES FROM GLOBAL X - AXIS
|        ========================================================
--------------------------------------------------------------------------------
| NUM |      Tbh      |      Tb      |      Phi      |      Ta      |    Theta
--------------------------------------------------------------------------------
|     |               |              |               |              |
|  1  |  2.42302E+02  | 2.47582E+02  |  1.18541E+01  | 2.42302E+02  | 0.00000E+00
|  2  |  2.11392E+02  | 2.16672E+02  |  1.26747E+01  | 2.11392E+02  | 0.00000E+00
|  3  |  2.64415E+02  | 2.69695E+02  |  1.13561E+01  | 2.64415E+02  | 0.00000E+00
|  4  |  2.60531E+02  | 2.65811E+02  |  1.14390E+01  | 2.60531E+02  | 0.00000E+00
|  5  |  2.56402E+02  | 2.61902E+02  |  1.17625E+01  | 2.56402E+02  | 0.00000E+00
|  6  |  2.62668E+02  | 2.67948E+02  |  1.13932E+01  | 2.62668E+02  | 0.00000E+00
|  7  |  2.51180E+02  | 2.56460E+02  |  1.16464E+01  | 2.51180E+02  | 0.00000E+00
|  8  |  2.24410E+02  | 2.29690E+02  |  1.23089E+01  | 2.24410E+02  | 0.00000E+00
|  9  |  2.46319E+02  | 2.51599E+02  |  1.17588E+01  | 2.46319E+02  | 0.00000E+00
| 10  |  2.10836E+02  | 2.16116E+02  |  1.26911E+01  | 2.10836E+02  | 0.00000E+00
| 11  |  2.16262E+02  | 2.21565E+02  |  1.25601E+01  | 2.16262E+02  | 0.00000E+00
| 12  |  2.33793E+02  | 2.39073E+02  |  1.20640E+01  | 2.33793E+02  | 0.00000E+00
|     |               |              |               |              |
--------------------------------------------------------------------------------
| NUM |   EXCURSION   |      X1      |      X2       |      S       |      W
--------------------------------------------------------------------------------
|     |               |              |               |              |
|  1  |  4.75910E+03  | 2.11812E+03  |  2.62981E+03  | 2.64888E+03  |
|  2  |  4.81447E+03  | 2.34889E+03  |  2.45570E+03  | 2.47611E+03  |
|  3  |  4.84817E+03  | 2.08814E+03  |  2.74760E+03  | 2.76586E+03  |
|  4  |  4.61923E+03  | 1.88032E+03  |  2.72728E+03  | 2.74568E+03  |
|  5  |  3.79772E+03  | 1.51818E+03  |  2.27029E+03  | 2.28982E+03  |
|  6  |  5.11476E+03  | 2.36320E+03  |  2.73848E+03  | 2.75680E+03  |
|  7  |  5.42058E+03  | 2.72954E+03  |  2.67772E+03  | 2.69646E+03  |
|  8  |  5.14544E+03  | 2.60370E+03  |  2.53049E+03  | 2.55030E+03  |
|  9  |  4.79854E+03  | 2.13549E+03  |  2.65160E+03  | 2.67051E+03  |
| 10  |  4.45362E+03  | 1.99211E+03  |  2.45246E+03  | 2.47289E+03  |
| 11  |  3.96489E+03  | 1.61137E+03  |  2.34533E+03  | 2.36563E+03  |
| 12  |  4.94682E+03  | 2.35253E+03  |  2.58305E+03  | 2.60247E+03  |
|     |               |              |               |              |
--------------------------------------------------------------------------------
| NUM |     ALPHA     |    Del X1    |    Del X2     |    Del S     |    CHECK
--------------------------------------------------------------------------------
|     |               |              |               |              |
|  1  |  2.85001E+02  | 4.47365E+00  |  6.70058E+00  | 6.74918E+00  |  TOUCHDOWN
|  2  |  3.15000E+02  | 4.41222E+00  |  5.46459E+00  | 5.51091E+00  |  TOUCHDOWN
|  3  |  3.44999E+02  | 4.79915E+00  |  7.63495E+00  | 7.68570E+00  |  TOUCHDOWN
|  4  |  1.49986E+01  | 4.16345E+00  |  7.46790E+00  | 7.51828E+00  |  TOUCHDOWN
|  5  |  4.50000E+01  | 3.20287E+00  |  6.05458E+00  | 6.10732E+00  |  TOUCHDOWN
|  6  |  7.50013E+01  | 5.52168E+00  |  7.55966E+00  | 7.61024E+00  |  TOUCHDOWN
|  7  |  1.05001E+02  | 6.24081E+00  |  7.07081E+00  | 7.12029E+00  |  TOUCHDOWN
|  8  |  1.35000E+02  | 5.28067E+00  |  5.97487E+00  | 6.02166E+00  |  TOUCHDOWN
|  9  |  1.64999E+02  | 4.59247E+00  |  6.86729E+00  | 6.91629E+00  |  TOUCHDOWN
| 10  |  1.94999E+02  | 3.61534E+00  |  5.44314E+00  | 5.48850E+00  |  TOUCHDOWN
| 11  |  2.25000E+02  | 2.86729E+00  |  5.32255E+00  | 5.36879E+00  |  TOUCHDOWN
| 12  |  2.55001E+02  | 4.88867E+00  |  6.35201E+00  | 6.39975E+00  |  TOUCHDOWN
|     |               |              |               |              |
--------------------------------------------------------------------------------------------

                                  CALCULATED RESULTS

            ===========================================================
            DIRECTION OF MOTION IS  110.00 DEGREES FROM THE GLOBAL X - AXIS
            ===========================================================

     STEP  1    HORIZONTAL MOVEMENT FROM ORIGIN IS  5.00000E+00
     -------

       RESTORING FORCE =  3.15889E+02 AT 308.1 DEGREES FROM  GLOBAL X - AXIS
       ==================================================================

       M - ROLL =                   M - PITCH =                   M - YAW =

                 ROTATION OF BODY =   -.06 DEGREES FROM GLOBAL X - AXIS
                 ==================================================
------------------------------------------------------------------------------------------
| NUM |        Tbh       |       Tb        |       Phi       |       Ta        |     Theta
------------------------------------------------------------------------------------------

   1     3.03751E+02       3.09031E+02       1.06066E+01       3.03751E+02       0.00000E+00
   2     2.61570E+02       2.66850E+02       1.14167E+01       2.61570E+02       0.00000E+00
   3     2.99533E+02       3.04813E+02       1.06799E+01       2.99533E+02       0.00000E+00
   4     2.67604E+02       2.72884E+02       1.12893E+01       2.67604E+02       0.00000E+00
   5     2.25249E+02       2.30646E+02       1.24188E+01       2.25249E+02       0.00000E+00
   6     2.18291E+02       2.23571E+02       1.24769E+01       2.18291E+02       0.00000E+00
   7     1.98626E+02       2.03906E+02       1.30672E+01       1.98626E+02       0.00000E+00
   8     1.78638E+02       1.83918E+02       1.37622E+01       1.78638E+02       0.00000E+00
   9     2.12785E+02       2.18065E+02       1.26340E+01       2.12785E+02       0.00000E+00
  10     2.07431E+02       2.12711E+02       1.27927E+01       2.07431E+02       0.00000E+00
  11     2.48277E+02       2.53639E+02       1.18025E+01       2.48277E+02       0.00000E+00
  12     2.84180E+02       2.89460E+02       1.09603E+01       2.84180E+02       0.00000E+00

------------------------------------------------------------------------------------------
| NUM |     EXCURSION    |       X1        |       X2        |        S        |       W
------------------------------------------------------------------------------------------

   1     4.76396E+03       1.80443E+03       2.94552E+03       2.96257E+03
   2     4.81886E+03       2.07391E+03       2.73273E+03       2.75109E+03
   3     4.85092E+03       1.91189E+03       2.92494E+03       2.94211E+03
   4     4.61979E+03       1.84367E+03       2.76417E+03       2.78233E+03
   5     3.79577E+03       1.55994E+03       2.22769E+03       2.24806E+03
   6     5.11078E+03       2.60430E+03       2.49561E+03       2.51570E+03
   7     5.41547E+03       3.02487E+03       2.38008E+03       2.40113E+03
   8     5.14077E+03       2.97522E+03       2.25659E+03       2.27878E+03
   9     4.79555E+03       2.32184E+03       2.46381E+03       2.48416E+03
  10     4.45331E+03       2.01191E+03       2.43248E+03       2.45309E+03
  11     3.96716E+03       1.57061E+03       2.38714E+03       2.40639E+03
  12     4.95104E+03       2.08861E+03       2.84877E+03       2.86639E+03

------------------------------------------------------------------------------------------
| NUM |       ALPHA      |     Del X1      |     Del X2      |      Del S      |     CHECK
------------------------------------------------------------------------------------------

   1     2.85004E+02       4.61348E+00       9.39445E+00       9.44882E+00       TOUCHDOWN
   2     3.14975E+02       4.70866E+00       7.51248E+00       7.56296E+00       TOUCHDOWN
   3     3.44952E+02       4.88545E+00       9.20002E+00       9.25401E+00       TOUCHDOWN
   4     1.49391E+01       4.17409E+00       7.77303E+00       7.82408E+00       TOUCHDOWN
   5     4.49316E+01       2.89112E+00       5.24159E+00       5.28992E+00       TOUCHDOWN
   6     7.49671E+01       5.13825E+00       5.73313E+00       5.77928E+00       TOUCHDOWN
   7     1.04995E+02       5.54742E+00       4.97912E+00       5.02316E+00       TOUCHDOWN
```

```
|  8  |   1.35024E+02  |  4.71009E+00  |  4.24995E+00  |  4.29174E+00  |   TOUCHDOWN
|  9  |   1.65050E+02  |  4.38121E+00  |  5.51846E+00  |  5.56403E+00  |   TOUCHDOWN
| 10  |   1.95065E+02  |  3.59982E+00  |  5.31233E+00  |  5.35733E+00  |   TOUCHDOWN
| 11  |   2.25065E+02  |  3.20848E+00  |  6.19364E+00  |  6.24393E+00  |   TOUCHDOWN
| 12  |   2.55032E+02  |  5.15929E+00  |  8.50386E+00  |  8.55646E+00  |   TOUCHDOWN
|     |                |               |               |               |
--------------------------------------------------------------------------------------
```

```
STEP  2    HORIZONTAL MOVEMENT FROM ORIGIN IS   1.00000E+01
-------

   RESTORING FORCE =  6.49358E+02  AT 297.1 DEGREES FROM  GLOBAL X - AXIS
   ======================================================================

  M - ROLL =                 M - PITCH =                M - YAW =

        ROTATION OF BODY =    -.20 DEGREES FROM GLOBAL X - AXIS
        =========================================================
--------------------------------------------------------------------------------
| NUM |      Tbh       |      Tb       |      Phi      |      Ta       |     Theta
--------------------------------------------------------------------------------
   1     3.71375E+02     3.76664E+02     9.61380E+00     3.71375E+02     0.00000E+00
   2     3.16341E+02     3.21621E+02     1.03963E+01     3.16341E+02     0.00000E+00
   3     3.35010E+02     3.40290E+02     1.01063E+01     3.35010E+02     0.00000E+00
   4     2.76876E+02     2.82156E+02     1.11017E+01     2.76876E+02     0.00000E+00
   5     2.00226E+02     2.05556E+02     1.30770E+01     2.00226E+02     0.00000E+00
   6     1.80954E+02     1.86234E+02     1.36759E+01     1.80954E+02     0.00000E+00
   7     1.53522E+02     1.58802E+02     1.48162E+01     1.53522E+02     0.00000E+00
   8     1.39535E+02     1.44815E+02     1.55194E+01     1.39535E+02     0.00000E+00
   9     1.81391E+02     1.86671E+02     1.36598E+01     1.81391E+02     0.00000E+00
  10     2.05792E+02     2.11072E+02     1.28425E+01     2.05792E+02     0.00000E+00
  11     2.88044E+02     2.93511E+02     1.10764E+01     2.88044E+02     0.00000E+00
  12     3.42585E+02     3.47865E+02     9.99540E+00     3.42585E+02     0.00000E+00
                                                                         0.00000E+00
--------------------------------------------------------------------------------
| NUM |   EXCURSION    |      X1       |      X2       |       S       |       W
--------------------------------------------------------------------------------
   1     4.76866E+03     1.61627E+03     3.13526E+03     3.15073E+03
   2     4.82307E+03     1.80218E+03     3.00612E+03     3.02282E+03
   3     4.85352E+03     1.74397E+03     3.09379E+03     3.11003E+03
   4     4.62051E+03     1.79634E+03     2.81181E+03     2.82966E+03
   5     3.79398E+03     1.59404E+03     2.19271E+03     2.21396E+03
   6     5.10696E+03     2.82671E+03     2.27125E+03     2.29329E+03
   7     5.41022E+03     3.31096E+03     2.09112E+03     2.11504E+03
   8     5.13592E+03     3.13590E+03     1.99302E+03     2.01810E+03
   9     4.79242E+03     2.50998E+03     2.27400E+03     2.29682E+03
  10     4.45316E+03     2.02150E+03     2.42282E+03     2.44350E+03
  11     3.96960E+03     1.52089E+03     2.43780E+03     2.45611E+03
  12     4.95541E+03     1.81028E+03     3.12866E+03     3.14472E+03
--------------------------------------------------------------------------------
| NUM |     ALPHA      |    Del X1     |    Del X2     |     Del S     |     CHECK
--------------------------------------------------------------------------------
   1     2.85008E+02     4.93881E+00     1.21876E+01     1.22479E+01     TOUCHDOWN
   2     3.14950E+02     4.79726E+00     9.98281E+00     1.00383E+01     TOUCHDOWN
   3     3.44906E+02     4.87682E+00     1.08769E+01     1.09340E+01     TOUCHDOWN
   4     1.48793E+01     4.18192E+00     8.17913E+00     8.23106E+00     TOUCHDOWN
   5     4.48631E+01     2.62612E+00     4.60317E+00     4.64803E+00     TOUCHDOWN
   6     7.49331E+01     4.67952E+00     4.33245E+00     4.37451E+00     TOUCHDOWN
   7     1.04988E+02     4.74623E+00     3.39007E+00     3.42884E+00     TOUCHDOWN
   8     1.35047E+02     4.05881E+00     2.94005E+00     2.97704E+00     TOUCHDOWN
   9     1.65101E+02     4.09106E+00     4.34809E+00     4.39019E+00     TOUCHDOWN
  10     1.95131E+02     3.59198E+00     5.24978E+00     5.29460E+00     TOUCHDOWN
  11     2.25131E+02     3.60455E+00     7.30347E+00     7.35895E+00     TOUCHDOWN
  12     2.55064E+02     5.22424E+00     1.12469E+01     1.13046E+01     TOUCHDOWN
                                                                         TOUCHDOWN
--------------------------------------------------------------------------------
```

```
-------------------------------------------------------------------------------------
|
|  STEP  3    HORIZONTAL MOVEMENT FROM ORIGIN IS  1.50000E+01
|  -------
|
|    RESTORING FORCE =  9.87122E+02  AT 293.3 DEGREES FROM  GLOBAL X - AXIS
|    ======================================================================
|
|   M - ROLL =               -  M - PITCH =      -          M - YAW = -      -
|
|            ROTATION OF BODY =   -.40 DEGREES FROM GLOBAL X - AXIS
|            ===================================================
-------------------------------------------------------------------------------------
| NUM |      Tbh      |      Tb      |      Phi      |      Ta      |     Theta
-------------------------------------------------------------------------------------
|     |               |              |               |              |
|  1  |  4.47146E+02  | 4.52507E+02  |  8.82855E+00  | 4.47146E+02  |  0.00000E+00
|  2  |  3.75176E+02  | 3.80462E+02  |  9.56135E+00  | 3.75176E+02  |  0.00000E+00
|  3  |  3.71008E+02  | 3.76290E+02  |  9.61120E+00  | 3.71008E+02  |  0.00000E+00
|  4  |  2.87999E+02  | 2.93279E+02  |  1.08885E+01  | 2.87999E+02  |  0.00000E+00
|  5  |  1.79936E+02  | 1.85230E+02  |  1.37315E+01  | 1.79936E+02  |  0.00000E+00
|  6  |  1.49916E+02  | 1.55196E+02  |  1.49883E+01  | 1.49916E+02  |  0.00000E+00
|  7  |  1.16981E+02  | 1.22261E+02  |  1.69000E+01  | 1.16981E+02  |  0.00000E+00
|  8  |  1.07881E+02  | 1.13161E+02  |  1.75715E+01  | 1.07881E+02  |  0.00000E+00
|  9  |  1.53060E+02  | 1.58340E+02  |  1.48379E+01  | 1.53060E+02  |  0.00000E+00
| 10  |  2.05509E+02  | 2.10789E+02  |  1.28511E+01  | 2.05509E+02  |  0.00000E+00
| 11  |  3.34498E+02  | 3.40114E+02  |  1.04256E+01  | 3.34498E+02  |  0.00000E+00
| 12  |  4.08346E+02  | 4.13632E+02  |  9.16961E+00  | 4.08346E+02  |  0.00000E+00
|     |               |              |               |              |
-------------------------------------------------------------------------------------
| NUM |   EXCURSION   |      X1      |      X2       |      S       |       W
-------------------------------------------------------------------------------------
|     |               |              |               |              |
|  1  |  4.77326E+03  | 1.54412E+03  |  3.20853E+03  | 3.22288E+03  |
|  2  |  4.82716E+03  | 1.62535E+03  |  3.18428E+03  | 3.19965E+03  |
|  3  |  4.85601E+03  | 1.63557E+03  |  3.20299E+03  | 3.21843E+03  |
|  4  |  4.62135E+03  | 1.74059E+03  |  2.86790E+03  | 2.88541E+03  |
|  5  |  3.79230E+03  | 1.62205E+03  |  2.16375E+03  | 2.18595E+03  |
|  6  |  5.10326E+03  | 3.02952E+03  |  2.06628E+03  | 2.09048E+03  |
|  7  |  5.40484E+03  | 3.57488E+03  |  1.82376E+03  | 1.85112E+03  |
|  8  |  5.13094E+03  | 3.37468E+03  |  1.75084E+03  | 1.77932E+03  |
|  9  |  4.78917E+03  | 2.69409E+03  |  2.08796E+03  | 2.11191E+03  |
| 10  |  4.45313E+03  | 2.02316E+03  |  2.42114E+03  | 2.44184E+03  |
| 11  |  3.97214E+03  | 1.46402E+03  |  2.49546E+03  | 2.51298E+03  |
| 12  |  4.95990E+03  | 1.62288E+03  |  3.31738E+03  | 3.33212E+03  |
|     |               |              |               |              |
-------------------------------------------------------------------------------------
| NUM |     ALPHA     |    Del X1    |    Del X2     |    Del S     |     CHECK
-------------------------------------------------------------------------------------
|     |               |              |               |              |
|  1  |  2.85010E+02  | 5.68100E+00  |  1.49396E+01  | 1.50070E+01  |   TOUCHDOWN
|  2  |  3.14925E+02  | 5.01738E+00  |  1.25115E+01  | 1.25720E+01  |   TOUCHDOWN
|  3  |  3.44860E+02  | 4.99282E+00  |  1.24537E+01  | 1.25137E+01  |   TOUCHDOWN
|  4  |  1.48203E+01  | 4.18230E+00  |  8.67531E+00  | 8.72826E+00  |   TOUCHDOWN
|  5  |  4.47946E+01  | 2.40148E+00  |  4.09531E+00  | 4.13743E+00  |   TOUCHDOWN
|  6  |  7.48983E+01  | 4.19429E+00  |  3.27201E+00  | 3.31034E+00  |   TOUCHDOWN
|  7  |  1.04981E+02  | 3.93883E+00  |  2.26899E+00  | 2.29490E+00  |   TOUCHDOWN
|  8  |  1.35071E+02  | 3.40697E+00  |  2.00429E+00  | 2.03689E+00  |   TOUCHDOWN
|  9  |  1.65152E+02  | 3.74629E+00  |  3.37428E+00  | 3.41360E+00  |   TOUCHDOWN
| 10  |  1.95198E+02  | 3.39060E+00  |  5.23898E+00  | 5.28377E+00  |   TOUCHDOWN
| 11  |  2.25196E+02  | 4.02936E+00  |  8.63780E+00  | 8.69940E+00  |   TOUCHDOWN
| 12  |  2.55094E+02  | 5.45269E+00  |  1.41801E+01  | 1.42432E+01  |   TOUCHDOWN
|     |               |              |               |              |
-------------------------------------------------------------------------------------
```

```
--------------------------------------------------------------------------------
|
|  STEP  4    HORIZONTAL MOVEMENT FROM ORIGIN IS  2.00000E+01
|  -------
|
|    RESTORING FORCE =  1.32351E+03  AT 291.1 DEGREES FROM  GLOBAL X - AXIS
|    ===========================================================================
|
|   M - ROLL =                 M - PITCH =                  M - YAW =
|
|              ROTATION OF BODY =   -.67 DEGREES FROM GLOBAL X - AXIS
|              ====================================================
--------------------------------------------------------------------------------
| NUM |     Tbh       |     Tb       |     Phi      |      Ta      |    Theta
--------------------------------------------------------------------------------
|     |               |              |              |              |
|  1  | 5.26823E+02   | 5.32303E+02  | 8.22821E+00  | 5.26823E+02  | 0.00000E+00
|  2  | 4.38291E+02   | 4.43623E+02  | 8.89237E+00  | 4.38291E+02  | 0.00000E+00
|  3  | 4.07443E+02   | 4.12741E+02  | 9.19079E+00  | 4.07443E+02  | 0.00000E+00
|  4  | 3.01399E+02   | 3.06679E+02  | 1.06473E+01  | 3.01399E+02  | 0.00000E+00
|  5  | 1.64545E+02   | 1.69825E+02  | 1.43258E+01  | 1.64545E+02  | 0.00000E+00
|  6  | 1.24728E+02   | 1.30008E+02  | 1.63852E+01  | 1.24728E+02  | 0.00000E+00
|  7  | 8.85883E+01   | 9.38683E+01  | 1.93087E+01  | 8.85883E+01  | 0.00000E+00
|  8  | 8.30873E+01   | 8.83673E+01  | 1.99065E+01  | 8.30873E+01  | 0.00000E+00
|  9  | 1.27964E+02   | 1.33244E+02  | 1.61836E+01  | 1.27964E+02  | 0.00000E+00
| 10  | 2.06831E+02   | 2.12111E+02  | 1.28109E+01  | 2.06831E+02  | 0.00000E+00
| 11  | 3.89010E+02   | 3.94815E+02  | 9.83748E+00  | 3.89010E+02  | 0.00000E+00
| 12  | 4.83914E+02   | 4.89255E+02  | 8.47359E+00  | 4.83914E+02  | 0.00000E+00
|     |               |              |              |              |
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| NUM |  EXCURSION    |      X1      |      X2      |      S       |      W
--------------------------------------------------------------------------------
|     |               |              |              |              |
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|  2  | 4.83108E+03   | 1.56605E+03  | 3.24456E+03  | 3.25895E+03  |
|  3  | 4.85836E+03   | 1.60141E+03  | 3.23779E+03  | 3.25259E+03  |
|  4  | 4.62234E+03   | 1.67482E+03  | 2.93407E+03  | 2.95118E+03  |
|  5  | 3.79082E+03   | 1.64353E+03  | 2.14136E+03  | 2.16447E+03  |
|  6  | 5.09971E+03   | 3.20968E+03  | 1.88361E+03  | 1.91012E+03  |
|  7  | 5.39933E+03   | 3.80943E+03  | 1.58520E+03  | 1.61657E+03  |
|  8  | 5.12579E+03   | 3.58692E+03  | 1.53470E+03  | 1.56708E+03  |
|  9  | 4.78578E+03   | 2.87177E+03  | 1.90806E+03  | 1.93423E+03  |
| 10  | 4.45325E+03   | 2.01542E+03  | 2.42895E+03  | 2.44958E+03  |
| 11  | 3.97489E+03   | 1.39887E+03  | 2.56129E+03  | 2.57813E+03  |
| 12  | 4.96453E+03   | 1.55477E+03  | 3.38650E+03  | 3.40023E+03  |
|     |               |              |              |              |
--------------------------------------------------------------------------------
| NUM |    ALPHA      |    Del X1    |    Del X2    |    Del S     |    CHECK
--------------------------------------------------------------------------------
|     |               |              |              |              |
|  1  | 2.85012E+02   | 6.37160E+00  | 1.79234E+01  | 1.79984E+01  |  TOUCHDOWN
|  2  | 3.14900E+02   | 5.64757E+00  | 1.48301E+01  | 1.48963E+01  |  TOUCHDOWN
|  3  | 3.44816E+02   | 5.36863E+00  | 1.37911E+01  | 1.38544E+01  |  TOUCHDOWN
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|  6  | 7.48624E+01   | 3.72442E+00  | 2.48751E+00  | 2.52251E+00  |  TOUCHDOWN
|  7  | 1.04973E+02   | 3.19975E+00  | 1.49547E+00  | 1.52506E+00  |  TOUCHDOWN
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|  9  | 1.65205E+02   | 3.36938E+00  | 2.58425E+00  | 2.61969E+00  |  TOUCHDOWN
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| 12  | 2.55123E+02   | 6.19055E+00  | 1.70754E+01  | 1.71451E+01  |  TOUCHDOWN
|     |               |              |              |              |
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APPENDIX 2A

DIVING SURVEY

REPORT ON THE INITIAL INVESTIGATION INTO THE LOSS OF THE "OCEAN RANGER CONDUCTED BY MOBIL OIL USING THE VESSELS "BALDER CABOT" AND "POLARIS V"

REPORT ON THE INITIAL INVESTIGATION INTO THE LOSS OF THE "OCEAN RANGER" CONDUCTED BY MOBIL OIL USING THE VESSELS "BALDER CABOT" AND "POLARIS V".

FEB. 19TH, 1982 TO FEB. 23RD, 1982

BY

GLENN R. COBB, B.Sc., C. Eng.
FOR THE

PETROLEUM DIRECTORATE
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

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1. SUMMARY
2. APPENDIX 1 - Polaris V Report on Fathometer Data (Simrad EQ.)
3. APPENDIX 2 - LOG - 19th to 23rd February, 1982
4. APPENDIX 3 - Diving personnel
5. APPENDIX 4 - Investigating and observing personnel
6. APPENDIX 5 - Details of survey vessels

SUMMARY

This initial investigation had three objectives namely:-

1. To locate the Ocean Ranger in relation to the J-34 wellhead.
2. To investigate the condition of the wellhead and the Blow out preventer stack (B.O.P.)
3. To confirm that the well was secure.

The plan of operation was for the Polaris V towing a variable depth sidescan sonar to locate the rig and drop a buoy at each of the four corners. The Polaris V was to work on a grid 6km x 6 km centered on the known position of the J-34 wellhead and then gradually work its way in. Unfortunately because of numerous technical problems this plan was never put into action and after the Polaris V had located the rig's anchor buoys the Balder Cabot moved to the edge of the anchor pattern and sighting a small oil slick inched its way inside using its Echo sounder and sonar. As the slick was approached small droplets of oil could be seen surfacing and when passing through the slick the ship's Echo Sounder (fathometer) recorded a water depth of 79m with an echo being returned from an object 23m below the surface. This information seemed to indicate that we had passed over a part of the rig the depth of the object (56m) being consistent with the distance from the underside of the rig's pontoon to the top of the upper deck.

The Polaris V was then asked to try and get a fix on the position and locate the wellhead and mark it with a buoy. This was done and on the third day out a dive was made with a 'Mantis' submersible on the assumed wellhead position. Unfortunately the buoy had been put down with over 60 ft. of slack in the cable and was off line when our dive was made. The diver found himself amidst rig debris and in an attempt to locate the wellhead trapped his umbilical cord. This took over two hours to free, after which the divers became very concerned about diving conditions. It was later established that the marker buoy was dropped further from the wellhead than was originally thought.

...2

It was then decided that dives would only be made at locations which could be accurately pinpointed. The most accurate detection equipment available to us was the side scan on the Polaris V which then started to malfunction. They had started with three side scan units but by 9:00 o'clock on the third day they were down to trying to make one good one out of the three. Problem after problem then started to plague the mission and when eventually the side scan was working they were reduced to running random passes close by the Balder Cabot in a vain attempt at locating the wellhead. After a few passes the side scan would then break down and bring proceedings to a halt. Some of the side scan data was analyzed on the Balder Cabot but thought to be inconsistent with the verbal communications between the ships. This series of events gave rise to mass confusion and a lack of confidence amongst the diving personnel in the side scan information. Thus by the end of the fourth day it became obvious to all parties that in order for the mission to be successful it would be necessary to re-equip the Balder Cabot so that it would be capable of accurately locating its own position and also provide it with remote control diving equipment so that in the first instance dives could be made without risk of human life.

The Balder Cabot returned to St. John's on the 23rd of February, 1982 and the Polaris V was left hopefully to try and repair its side scan equipment and start to map the area as originally planned. However, the side scan equipment could not be repaired due to lack of spare parts and the Polaris V returned to St. John's the following day.

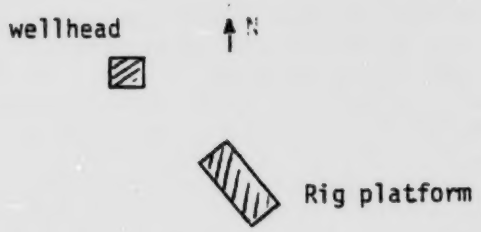
Thus none of the original objectives were achieved and the only information, albeit unsubstantiated, which was brought back was a written report from one of the operators on the Polaris V interpreting some fathometer data, a copy of this report is contained in Appendix 1. A log of each day's events is contained in Appendix 2, and some details of the diving personnel are included in Appendix 3. A list of personnel conducting and observing the investigation is detailed in Appendix 4 and some information on both vessels is contained in Appendix 5.

Glenn R Cobb

Glenn R. Cobb, Surveyor
to Lloyd's Register of
Shipping

APPENDIX 1

Polaris V Report on Fathometer Data (Simrad EQ.)



"The rig is believed to be 120m from the wellhead position on a true bearing of about 120°. There is a possibility that the platform itself has overturned, but there is as yet still no definitive evidence.

Wreckage and debris seems to be concentrated about the wellhead and to the northeast and west of the platform. Three anchor cables leading from the rig have been found so far. One from the northeast corner, a second from the west side and another from the southern side. There is not enough evidence yet to detail these or the other cables properly."

Polaris V Feb. 22nd, 1982

SIGNED I. COOKSON
Geophysicist

APPENDIX 2

LOG 13-2-82

Prior to Departure: Installing sonar equipment

11:05 Depart St. John's

15:00 Meeting with:
Sid Hynes, Captain - Balder Cabot
Max Ruelokke, Hydrospace Marine Services
Ron Page, Mobil Oil Representative
Carmen Costello, Odeco Structural Engineer
Glenn Cobb, Petroleum Directorate
Jan Merta, E.M.R.

Re: Basic plan of operations

LOG 20-2-82

01:00 Arrive Sedco 706 and calibrated sonar equipment

11:00 Polaris V reported sighting anchor buoys 6, 5, & 4

11:25 Weather report from 706.

12:00 Cable attached to 8" dia. pipe sonar tube to prevent vibration.

12:25 Ordered from Mobil Base 2 additional Dynamic Positioning (DP) anchors and 3 transponders for DP system.

12:30 Polaris V reported navigation and side scan under repair - requested Polaris locate anchor buoys 8 & 9

12:50 Received weather forecast from Sedco 706

13:20 Steaming toward J-34 location inside anchor pattern sighted two small traces of oil.

13:50 Requested frequency of Blow Out Preventer (B.O.P.) Pinker from Mobil Base.

14:20 Polaris V reported buoys 2, 7 & 10 missing.

15:15 Polaris V reported anchor buoys positions from J-34 wellhead location.

No. 1 1613m 235°
No. 2 missing
No. 3 1427m 288°
No. 4 1603m 322°
No. 5 1246m 357°

No. 6	1815m	024°	
No. 7	missing		
No. 8	1871m	088°	(half sunk)
No. 9	1703m	120°	
No. 10	missing		
No. 11	1422m	178°	
No. 12	1651m	200°	

15:30 Balder Cabot proceeds slowly towards oil traces with fathometer.

15:42 Balder Cabot directly over target - fathometer reading water depth 79m - depth to target 23m. Target assumed to be rig. Contacted Polaris V for position fix.

16:10 Echo from object 33 ft. on a bearing 044 120m from rigs position.

16:30 Sonar deployed and operating.

16:42 Rig sighted on sonar.

17:07 Polaris V drops buoy in vicinity of wellhead position

17:25 Balder Cabot dropped taut wire and went on DP within 50 ft. of buoy location

17:45 Balder Cabot captain received call from CBC and was referred to Mobil P.R. St. John's

17:50 Polaris V requested to make all shore communicacions through Balder Cabot

19:30 Balder Cabot retrieved taut wire came off D.P.

19:35 Preliminary evaluation as a result of two side scan sweeps by Polaris V indicates rig upside down.

LOG 21-02-82

05:00 Weather good for diving - requested side scan information from Polaris - divers preparing both submarines.

05:15 Polaris V reporting no side scan information available. Polaris requested to pass to Balder Cabot results of previous days sounding survey. Polaris V requested to continue scanning when equipment functional in immediate area of assumed rig position.

...3

05:30 Steaming to location

06:12 Balder Cabot moved inside buoy anchor pattern

06:50 On location by wellhead buoy

07:00 Balder Cabot on D.P. divers on standby for briefing. Polaris V running sidescan lines.

08:00 Polaris V reported sidescan down. Decision made to dive on wellhead without additional information.

08:10 Divers briefing

08:40 Mantis 9 launched with pilot Ian Blamire

09:00 Polaris V called - trying to assemble useable side scan sonar from 3 on board

09:15 Mantis 9 spotted anchor cable (No. 5) laying on sea bed and pieces of debris, visibility poor, camera flickering.

09:50 Mantis 9 locates 50 ft. section of MR6B Vetco Marine riser pipe, believed to be deck cargo, and small pipe structure. Diver noted that some of the debris was underneath No. 5 anchor cable.

10:00 Polaris V advised that after new side scan run that wellhead position 100 ft. ahead of Balder Cabot's present position. Decision made to move Balder Cabot ahead.

10:05 Mantis 9 returning to Balder Cabot, DP clump weight, umbilical fouled under door in tank on seabed. Tank reported 3 ft. dia. 5 ft. long colour light blu

12:20 Mantis 9 frees snagged cable.

12:25 Polaris V requested to set on wellhead and locate on Balder Cabot and report position.

12:30 Mantis 9 directly under Balder Cabot on seabed adjacent to DP clump - taking turns out of cable.

13:00 Balder Cabot out of D.P. mode.

13:15 Divers report that Mantis 9 has experienced a loss of function in one of the manipulator arms - estimated 1½ hours to repair.

...4

14:25 Balder Cabot located over new wellhead position as advised by Polaris V. Balder Cabot on DP mode.

14:40 Balder Cabot off DP mode to change position.

15:00 Balder Cabot relocated and put in DP mode.

15:30 Divers requested additional position and sea floor data prior to commencing dive. Polaris V reported side scan now functional. Requested Polaris V to run side scan line alongside Balder Cabot.

16:00 Polaris V running side scan line along Balder Cabot.

16:10 Polaris V reports indications of debris around wellhead and rig position to S.E. of wellhead.

16:15 Polaris V reports debris from wellhead to rig bearing 110° approximately 200m.

16:30 Diving operations suspended for the day. Polaris V commencing 2nd pass starboard side. Zodiac to be dispatched to take slack out of wellhead buoy line.

16:35 Zodiac launched with 3 men aboard.

16:38 Polaris V reporting good image of 4 legs of rig - continuing to scan for more detail.

16:45 Zodiac returned to Balder Cabot, 60 ft. taken out of line.

17:00 Balder Cabot off DP mode - operations suspended for the day. Polaris V continuing to sweep with sidescan.

20:10 Ron Page left Balder Cabot to join Zapata Ugland.

22:40 Ron Page left Zapata Ugland and rejoined Balder Cabot.

LOG 22-2-82

07:00 Seas O.K. for diving but visibility 1/8 mile below safety requirement for divers of 1/2 mile.

...5

07:45 Polaris V advises side scan not operating.

08:40 Zodiac launched to transfer side scan and fathometer data to Balder Cabot.

08:55 Zodiac returns to Balder Cabot.

09:20 Analyzed side scan - could not find any information to aid divers. Fathometer data indicates possible rig location. Divers plotted data to attempt to establish rig location and orientation. With data given this was not possible.

10:00 Advised Polaris V data received did not show in-information as indicated verbally. Discovered we received wrong line runs.

10:40 Balder Cabot put alongside Polaris V to transfer additional data.

11:30 Evaluation of new information not suitable to establish positions for jump dives. Polaris V was requested to set Balder Cabot subsea transponder 250 ft. on bearing 120° from wellhead for D.P. positioning to give Balder Cabot reference point for seafloor survey.

12:00 Balder Cabot sonar not operating.

12:40 Transferred transponder from Balder Cabot to Polaris V.

13:30 Polaris V set transponder 290 ft. bearing 120° true from wellhead location. May have had slight southern drift while setting. Had problem with plot to establish Balder Cabot position in relation to rig with data available from Polaris V.

13:45 Discovered Sonar Junction box flooded. Ordered additional spares from Mobil Base.

14:30 Balder Cabot sonar repaired and operational. Polaris V running side scan survey.

16:00 Pull taut wire, move vessel forward.

16:35 Polaris V on side scan line, side scan unit caught on transponder buoy line shifting its position. Polaris V reported loss of side scan unit.

....6

17:00 Balder Cabot surveyed sea floor with sonar and passed over rig using fathometer.

19:00 Balder Cabot steaming to St. John's for additional equipment.

Log 23-2-82

11:00 Arrived St. John's

APPENDIX 3

DIVING PERSONNEL

Hydrospace Marine Services

Max Ruelokke - General Manager

Submersible Team

Colin Williams - Operations Controller

Ian Blamire - Senior Pilot
Chris Chamberlain - Senior Pilot

Dan Whelan - Pilot Technician
Robert Bourque - Pilot Technician

Submersibles - Mantis 8 & Mantis 9

Standby Crew - Dry Suit Divers

Kerry Wiscombe
Wayne Betts
Ted Gosse

Vessel's detection and navigation equipment includes:

1. Argo Satellite, Loran C & Mini Ranger computerized navigation system.
2. ORE 160 Sonar Side Scan system.
3. Klein 100K Side Scan Sonar with K-Maps (high resolution system) - not operable during this initial survey.
4. Simrad E.Q. Echo Sounder
5. Furuno Echo Sounder
6. Two ED 9040 Echo Sounders
7. Texas instruments DSF 4 high resolution seismic system

APPENDIX 4

PERSONNEL

The following is a complete list of the personnel conducting and observing the investigation:

Ron Page - Mobil Oil

Max Ruelokke - Hydrospace Marine Services - Diving Operations

Sidney Hynes - Balder Cabot - Ship's Master

OBSERVERS

Glenn Cobb - Petroleum Directorate - Government of Newfoundland and Labrador

Jan Merta - Canada Oil and Gas Lands Administration - Diving Systems Engineer

Carmen Costello - Odeco - Structural Engineer

APPENDIX 5

DETAILS OF SURVEY VESSELS

BALDER CABOT

Built: 1981, Marystown Shipyard, Newfoundland

Principal Dimensions: Length overall 72.07m, breadth 16.41m, depth 6.51

Gross Tonnage: 1599

Flag: British

Owner: Deasea Ltd. (Ugland UK Ltd.) London U.K.

Managed by: Parley Augustsson A/S

Ship type: Diving support ship for offshore installation with Kongsberg Dynamic Positioning System

Vessel's detection and navigation equipment includes:

1. Magnavox Dual Channel Satellite Navigator MX 1107 RS
2. Furuno Echo Sounder
3. Wesmar SS 265 Digital Color Sonar - installed for this investigation in an 8" pipe attached to the side of the moonpool.

Diving Equipment: Two mantis submersibles with ancillary equipment operated by a 5 man team.

POLARIS V

Built: 1951 A.M. Liaaen Skibs & M/V - Alesund

Principal Dimensions: Length overall 53.17m, breadth 8.56m, depth 4.53m

Gross Tonnage: 585

Flag: Canadian

Registered Owner: Carino Co. Ltd., St. John's, Newfoundland

Ship type: Listed in Lloyd's Register Book as General Cargo/Sealer although now equipped and operating as a seismic research vessel.

...2

APPENDIX 2B

DIVING SURVEY

REPORT ON THE SECOND INVESTIGATION INTO THE LOSS OF THE "OCEAN RANGER" CONDUCTED BY MOBIL OIL USING THE VESSELS "BALDER CABOT" AND "POLARIS V".

ERRATA

(Page 8)

The numbering of the portholes in the diagram of starbord column 3 is incorrect, and should follow the numbering scheme shown in Figure 4.1A, Volume I (ie. numbering should be reversed).

Also, later review of the survey videotapes (as well as results from the Royal Commission diving survey) revealed that porthole number 2 was broken, as well as porthole 1.

REPORT ON THE SECOND INVESTIGATION INTO THE LOSS OF THE "OCEAN RANGER" CONDUCTED BY MOBIL OIL USING THE VESSELS "BALDER CABOT" AND "POLARIS V".

FEB. 28TH, 1982 TO MARCH 3RD, 1982

BY

GLENN R. COBB, B. Sc., C. Eng.

FOR THE

PETROLEUM DIRECTORATE
GOVERNMENT OF NEWFOUNDLAND & LABRADOR

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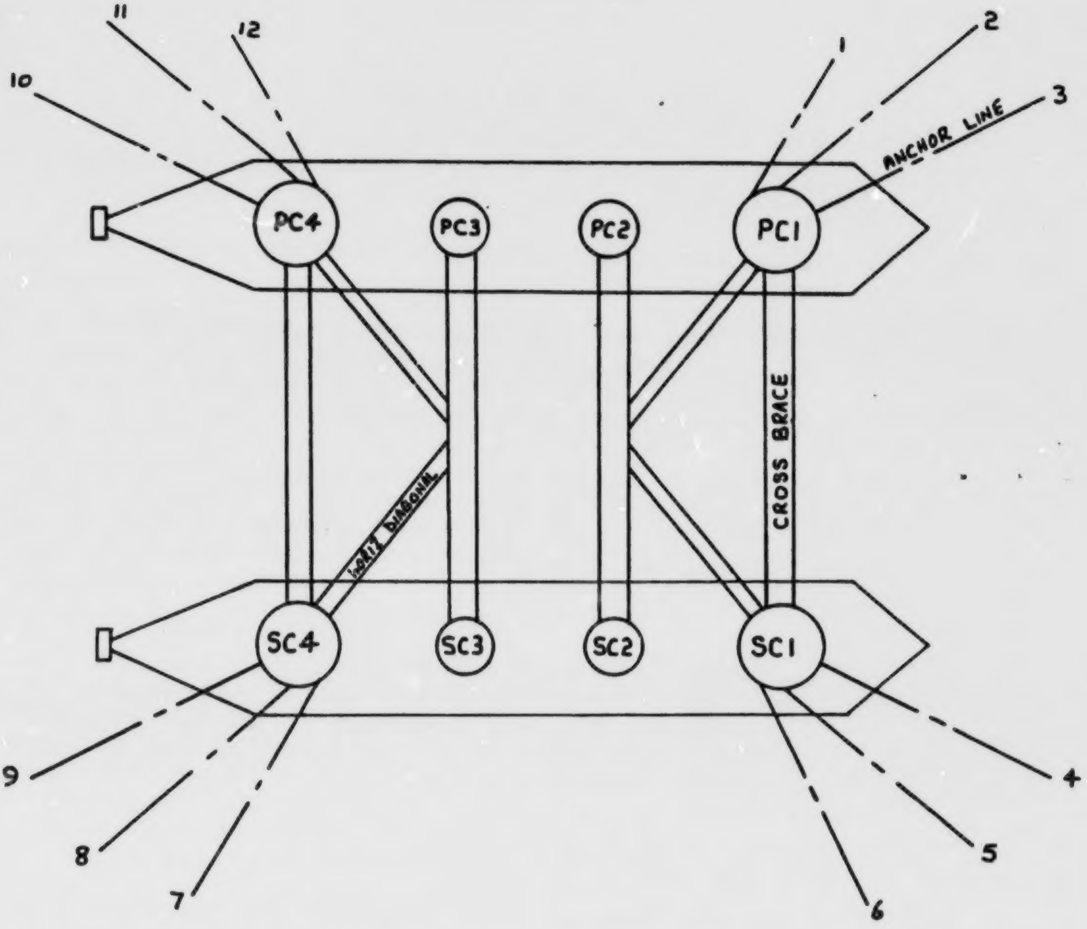
6. Photographs of Equipment and some RCV Video 13-21

This Report should be read in conjunction with the one on the initial investigation for the period February 19th, 1982 to February 23rd, 1982.

NOMENCLATURE


11
12
10
1
2
3
ANCHOR LINE
PC4
PC3
PC2
PC1
CROSS BRACE
HORIZ DIAGONAL
SC4
SC3
SC2
SC1
9
8
7
4
5
6

PLAN VIEW OF RIG PONTOONS

AND COLUMNS

All descriptions of the Rig contained in this Report are written in the context of the Rig being in an upright position.

Abbreviations Used

RCV - Remote Control Vehicle

DP - Dynamic Positioning

B.O.P. - Blow-Out Preventer

SUMMARY AND CONCLUSIONS

This second investigation had the same three objectives as the initial one namely:-

1. To locate the Ocean Ranger in relation to the J-34 wellhead.
2. To investigate the condition of the wellhead and the Blow-Out Preventer stack (B.O.P.).
3. To confirm that the well was secure.

The 'Balder Cabot' embarked upon this second investigation with the addition to its diving equipment of a Recon J Remote Control Vehicle (RCV). Telex equipment was also installed to improve communications with Mobil Base and modifications were carried out to the Wesmar Digital Color Sonar System to try and improve on its reliability.

The Balder Cabot proceeded directly to the site and when located in the oil slick inside the buoy pattern sent down the RCV. It soon became apparent that the slick was not over the rig and presumably had been moved by the wind and current. Debris was seen on the seabed over the entire area which was scanned. It was soon recognized that the RCV was obviously the right vehicle for this investigation being able to cover large areas very quickly aided by the adept skill of its pilot.

When the rig was eventually located it was the Port Pontoon which was scanned first. This was the first conclusive evidence we had which showed that the rig had overturned;in addition we deduced that the rig's heading had changed from 312° to 110°. Both the Port and Starboard pontoons were damaged at the top of the forward ends, the port damage appearing to be a little more extensive than the starboard. Close examination of six of the columns PC1, PC2, PC4, SC1, SC3 & SC4, the pontoons and isolated areasofcross braces and vertical diagonals revealed no signs of damage which could be considered as contributing to the accident. It should be pointed out at this stage that not every square foot of the members was examined but rather the critical areas in way of the connections to the pontoons and some of the members adjoining the columns.

Damage was however seen at the tops of some of the columns particularly PC2 & SC4 which was evidently as a result of the rig impacting on the seabed.

All structure above the upper deck has been completely sheared off or crushed. The seabed is littered with debris from the deck;items sighted include containers, drill pipe, riser pipe, flare boom, part of the derrick, analysts shack, air condition control units and electrical units as yet unidentified.

All twelve roller fairleads were examined on the four corner columns PC1, PC4, SC1 & SC4 and all found to be intact; however, the anchor wires for anchors 1,2,4, & 5 were missing. The wires for the remaining eight anchors were taut around the sheaves and it was deduced that these were presumably still attached to the anchors.

The ballast control room was located in column SC3 and it was seen that all four windows had the deadlights closed, the glass was broken in window No. 1 but intact in the other three.

Thus the pattern of the remaining anchors coupled with the damage to the pontoon tips and the rig's present heading seem to support the theory that the rig may have overturned end to end rather than Port to Starboard, the wind plus the tension in the six aft end anchor cables being responsible for the shift in the rig's position away from the wellhead.

It was reported from the Polaris V that the wellhead was located 97 metres from the centre of the rig but that this figure could be out by as much as ± 20 metres. The only really detailed information regarding the exact disposition of the rig to wellhead will be available when all the sidescan data from the Polaris V has been analyzed and plotted. The co-ordinates quoted for the two positions however were as follows:

Wellhead:	46°	43.558'	N	Lat.
	48°	50.140'	W	Long.
Rig Centre:	46°	43.528'	N	Lat.
	48°	50.051'	W	Long.

When the wellhead was located it was found to be intact and secure but surrounded by debris. Two sections of pipe are resting against the wellhead but not likely to cause any damage and a small steel container is adjacent to the base plate. The wellhead has now been marked with a pinger to aid future investigations.

The data which was brought back aboard the Balder Cabot includes 18 black and white video tapes from the RCV, tapes from the honeywell plotter used to track it and tapes of the Wesman Colour Sonar. It is understood that there is some commentary on the video tapes. The other tapes will require expert interpretation.

For future considerations there is still a lot of the rig's structure which has not been examined in detail and it is known that Mobil Oil are keen to locate the Lower Riser Package which they need to re-commence drilling operations on the well. Whilst it was stated earlier that no obvious signs of damage which could have caused the accident were apparent the nature of this examination did not lend itself to highlighting small fatigue fractures which could be a factor worthy of consideration. It may well be that many of the answers which we are now seeking will not be found unless the rig is salvaged which in view of the fact that its main buoyancy chambers are relatively intact must be considered feasible. However there are some very unique problems which would face a salvage team, not the least of which is the weather in this area.

The Long Term Charter for the Balder Cabot belongs to Petro Canada who have now requested the vessel back. It was mentioned however that Mobil Oil may continue investigations using a sister ship called Balder Baffin.

Thus this investigation achieved all three of its objectives and should be considered a success. The attitude towards the observers on the investigation was at all times good and relations cordial.

A Log of each day's events is included in Appendix 1 and details of the diving personnel are contained in Appendix 2. Appendix 3 lists the personnel conducting and observing the investigation and some photographs of the equipment used and some video results are included at the end of the report.

Glenn R Cobb

Glenn R. Cobb, Surveyor to
Lloyd's Register of Shipping
5 March 1982

APPENDIX 1

LOG 28-02-82

18:12 Depart St. John's

LOG. 1-03-82

07:15 Arrived on site - seas moderate - preparing equipment for site survey. Polaris V at 706 site calibrating navigation equipment due at J-34 at 10:00. CCG Bartlett standing by to deploy buoy with Polaris V.

07:52 Balder Cabot on DP mode.

08:50 RCV launched.

08:55 RCV returned to Balder Cabot.

09:01 RCV launched.

09:13 RCV returned to Balder Cabot.

09:25 Balder Cabot off DP mode to reposition.

09:35 Balder Cabot back on DP mode in centre of oil slick.

10:15 RCV launched - down to seabed to begin search. Debris located - anchor wire spotted (possibly No. 9). Flare boom located upside down and broken up.

11:13 RCV returned to Balder Cabot. Balder Cabot off DP mode to locate 150 ft. forward.

11:15 Balder Cabot moving.

11:18 Balder Cabot on new location on DP mode position 46°-43.7'N Lat. 48°-50.6'W long.

11:46 RCV launched

12:25 Flare boom again located - RCV sweeping entire area. Numerous pieces of debris located e.g. sheet metal name sign, ladder case, sections of pipe, valves, and some electrical connection boxes. RCV at end of range. Rig not located. Balder Cabot to relocate aft. Polaris V requested to locate on rig.

12:55 Balder Cabot off DP mode. Re-locating aft of present position.

13:17 Taut wire down, Balder Cabot in centre of rig confirmed by Echo Sounder & Sonar & by Polaris V. Taut wire clump weight lost.

13:55 New clump weight being attached.

13:57 Taut wire being lowered.

14:00 Balder Cabot on DP mode directly over centre of rig.

14:10 Underside of pontoon located - cross braces seen and keel coolers.

14:45 Forward end of pontoon buckled.

15:00 Located keel coolers & returned to forward end.

16:30 Started to work towards starboard side of rig but returned for more detailed examination of port, cross braces and columns scanned.

16:45 Anchor wire seen over aft port cross brace. Continuing to scan port side.

18:07 RCV returning to garage.

18:12 RCV docked in garage.

18:18 RCV returned to Balder Cabot.

19:30 RCV launched.

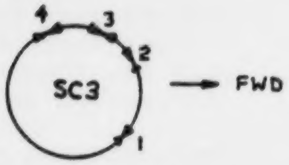
19:44 Returned to forward end of port pontoon - damage re-examined.

20:00 Balder Cabot position defined by satellite navigation as being:

Lat: 46^{o}-43.528' N
Long: 48^{o}-50.051' W

Balder Cabot estimated to be at centre of rig. Wire seen around base of SC4.

20:20 Ballast control room located in SC3 - deadlights were closed on all four windows. Glass broken in window No. 1. Glass intact on windows 2,3, & 4.



20:30 RCV returned to Balder Cabot.

20:54 Balder Cabot proceeding to new position trying to locate wellhead.

21:38 Balder Cabot on new location on DP mode. Sea state worsening. Vessel experiencing moderate swell.

22:05 Operations suspended for the day.

23:15 Balder Cabot off DP mode. Vessel jogging for the night. During the day the CCG Bartlett deployed a wreck buoy with the aid of the Polaris V at true bearing from the rig of 352° and .68 mile away.

LOG 2-03-82

08:31 RCV launched. Scanning trying to locate wellhead.

09:50 RCV launched. Balder Cabot moving to new position.

10:10 Balder Cabot in position on DP mode. RCV launched. Scanning bottom trying to locate wellhead.

11:44 RCV returned, Balder Cabot moving to new position.

12:55 Balder Cabot in position in DP mode.

13:00 RCV launched.

13:55 Wellhead B.O.P. located and scanned -two drill pipes laying on Blow -Out Preventer one at base the other laying against locater arm. Container adjacent to base of B.O.P. & debris in vicinity. One locater arm buckled. B.O.P. intact and secure.
Wellhead position Lat. 46°-43.558'N.
Long. 48°-50.14' W
RCV returned to Balder Cabot to collect pinger to be attached to B.O.P.

16:55 RCV launched to attach pinger - some difficulty experienced in relocating B.O.P. as Balder Cabot had unknowingly shifted position dragging its clump weight.

17:59 Pinger attached to B.O.P. No. 2 guide arm. Pinger thought to be manufactured by 'Mesotech' but not checked, has a frequency of 27 KHZ, with a 1 sec pulse and has a 90 day battery.

18:06 RCV returned to Balder Cabot.

18:12 Taut wire up Balder Cabot to reposition over rig.

18:55 Balder Cabot on DP at rig position.

19:07 Balder Cabot shifting taut wire trying to relocate on rig.

19:20 Balder Cabot shifting taut wire trying to relocate on rig.

19:32 RCV returned to garage beneath ship, Balder Cabot re-positioning.

19:45 Balder Cabot in position on DP mode.

20:00 RCV out, located PC1 scanning - examined fairlead 3 anchor wire still attached, fairlead No. 2 anchor wire missing.

21:20 RCV returned to Balder Cabot to check thruster.

21:23 RCV launched - PC2 located - slight damage to column seen below crane pedestal - crane pedestal sheared off and remaining portion above upper deck crushed.
PC1 fairleads examined: No. 1 anchor wire missing.
Horizontal cross brace examined between SC1 and PC1. No signs of damage.
SCI fairleads examined: No. 4 fairlead anchor wire missing
No. 5 fairlead anchor wire missing
No. 6 fairlead anchor wire still attached
SC1 slightly buckled at deckhead.

PC 4 fairleads examined No. 10 anchor wire attached
No. 11 anchor wire attached
but off of sheave
No. 12 anchor wire attached
but off of sheave

LOG 3-03-82

24:00 Drill floor located and riser pipe seen laying on cross brace between SC2 and PC2, approximately two sections of pipe still attached, the lower section with end collapsed and fractured the lower riser package was not located. When the RCV was at the underside of the drill floor the depth was reading 250' indicating that there was no likelihood of any structure standing above the drill floor. The sides of the moonpool were crushed.

Anchor wire located running across cross brace between PC 3 and SC 3.

01:00 SC4 located and scanned. Fairlead examined:-
- No. 7 anchor wire attached
- No. 8 anchor wire attached but off sheave
- No. 9 anchor wire attached but off sheave running over cross braces as indicated previously between PC3 & SC3.
- Deck structure in way of SC4 extensively damaged.

01:34 Operations suspended.

01:34 RCV returned to Balder Cabot.

01:40 Memorial service held for crew of Ocean Ranger with wreath laying ceremony conducted by Captain Sidney Hynes of the Balder Cabot.

Service consisted of:
- Introduction & opening remarks - Captain Sidney Hynes
- Reading of Psalm 23 - Max Ruelokke - Hydrospace
- Poem written and read by Dan Whelan - Hydrospace
- Wreath laying ceremony
- Hymn 'Eternal Father'

02:00 Balder Cabot off DP,returning to St. John's

18:30 Arrived St. John's.

APPENDIX 2

DIVING PERSONNEL

Hydrospace Marine Services -St. John's

Max Ruelokke - General Manager

Submersible Team

Colin Williams - Operations Controller

Ian Blamire - Senior Pilot

Chris Chamberlain - Senior Pilot

Dan Whelan - Pilot Technician

Robert Bourque - Pilot Technician

Submersibles - Mantis 8 & Mantis 9

Standby Crew - Dry Suit Divers

Robert Tremblett

Wayne Betts

Don Musgrave

Can-Dive Services - Vancouver

Doug Osborne - Co-ordinator remote control vehicle (RCV) operations

'Jered' Diving were sub-contracted by Can-Dive to perform RCV operations.

Jered - Houston, Texas

Bill Pederson - Crew Chief & RCV Pilot

Tim Webb - Mechanical Technician

Dick Wendell - Electrical Technician

Terry Daalker - Plotter (902 Honeywell)

Remote Control Vehicle - Recon J

APPENDIX 3

PERSONNEL

The following is a complete list of the personnel conducting and observing the investigation:

Ron Page - Mobil Oil

Rick McLeod - Mobil Oil

Max Ruelokke - Hydrospace Marine Services - Diving Operations

Doug Osborne - Can-Dive - Diving Operations

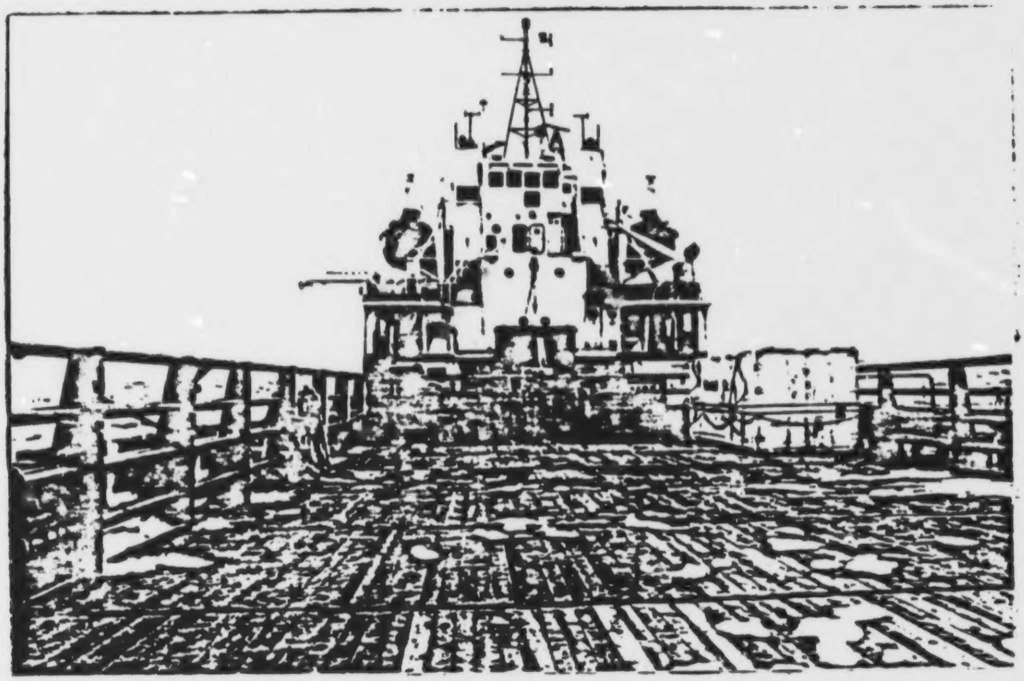
Sidney Hynes - Balder Cabot - Ship's Master

OBSERVERS

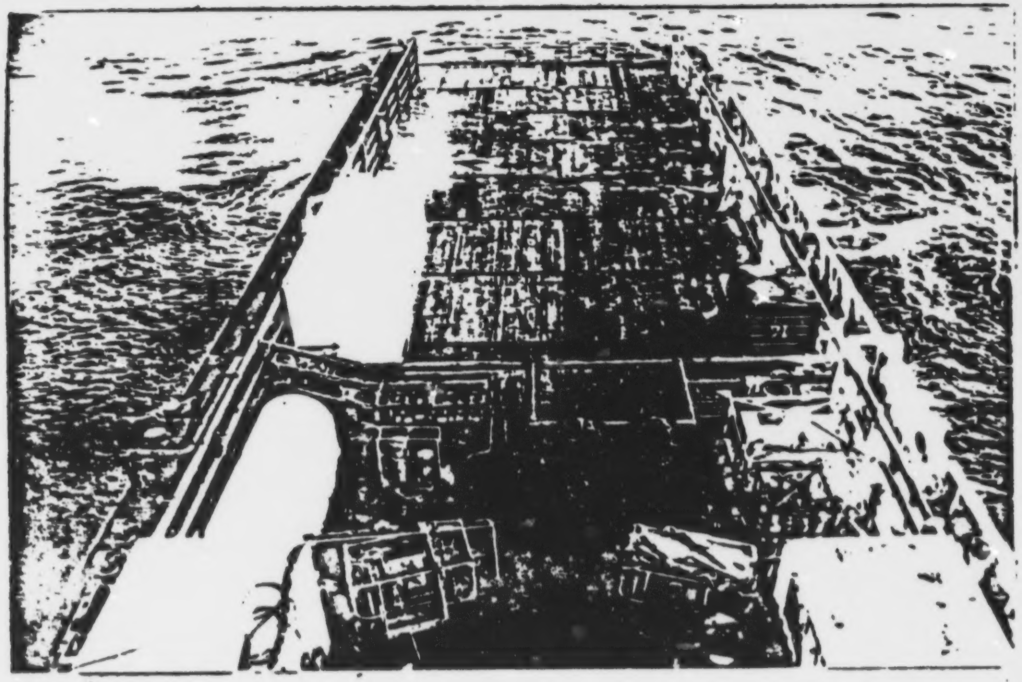
Glenn Cobb - Petroleum Directorate - Government of Newfoundland and Labrador

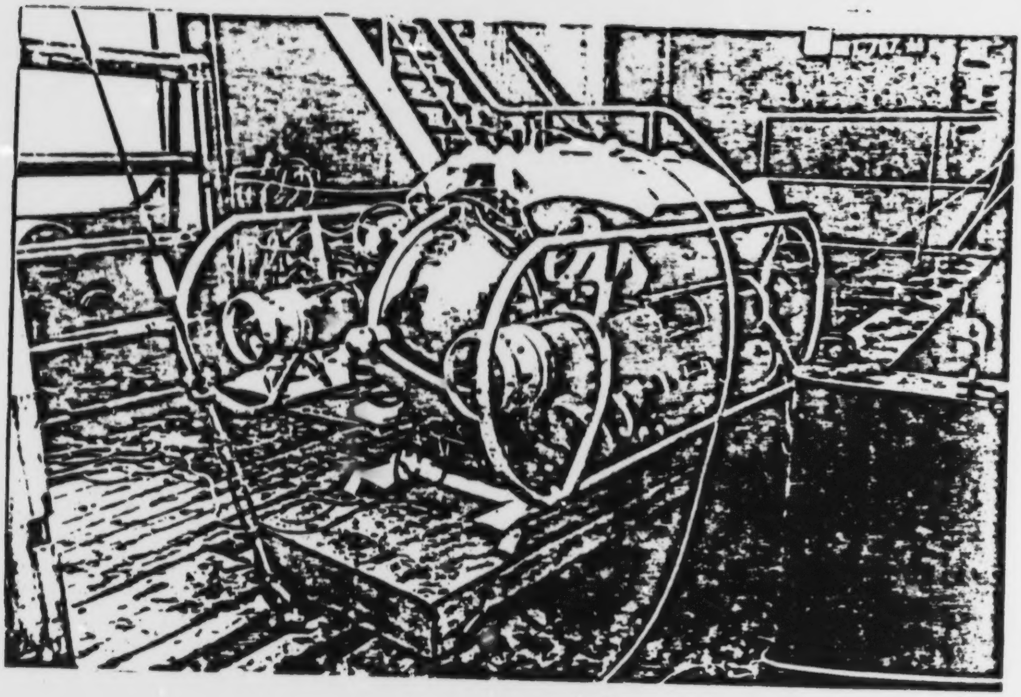
Perry Roberts - Energy, Mines & Resources - Civil Engineer

Carmen Costello - Odeco - Structural Engineer

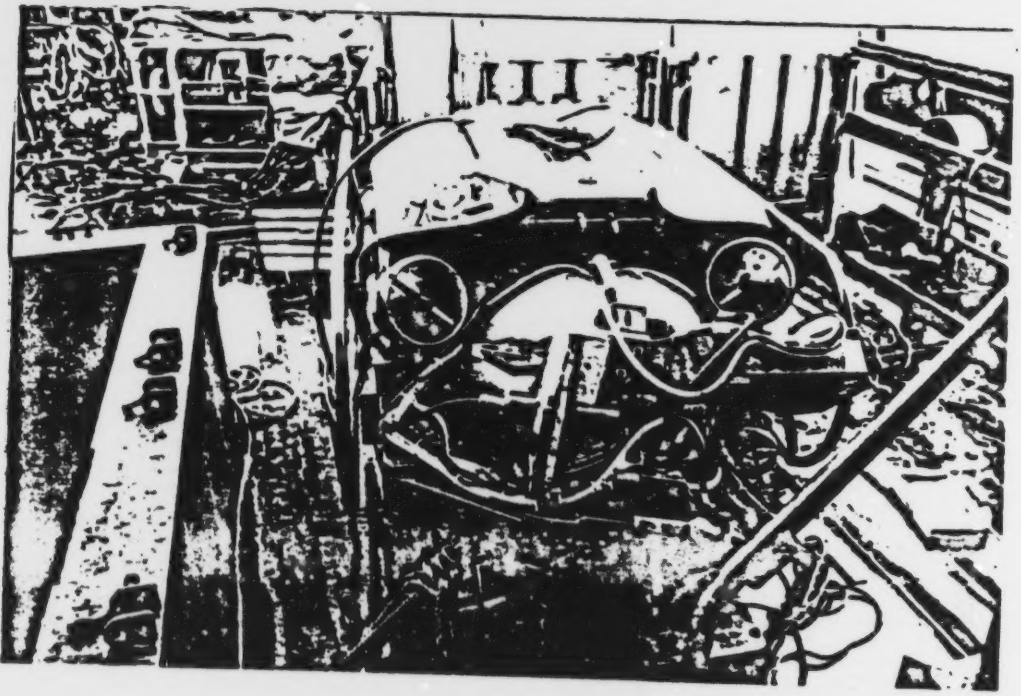


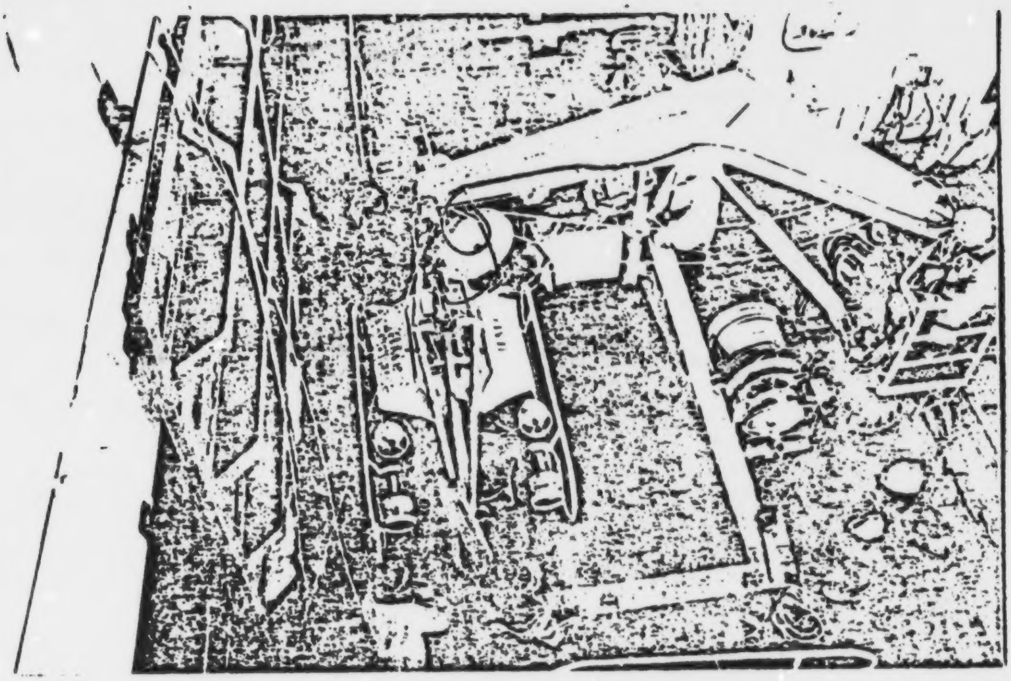
BALDER CABOT





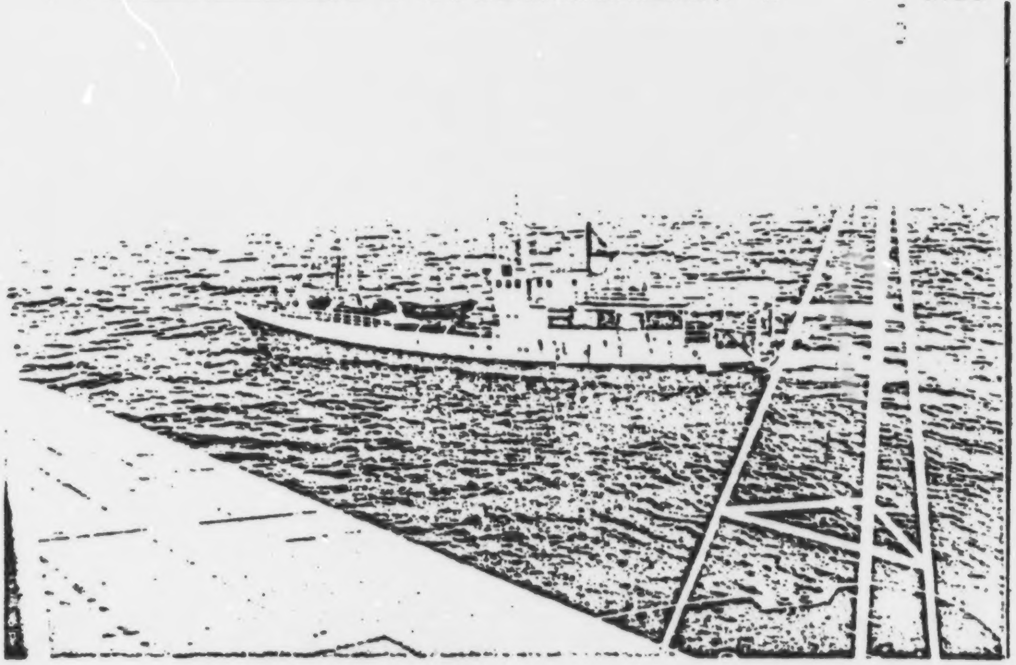
MANTIS 8 MANNED SUBMERSIBLE



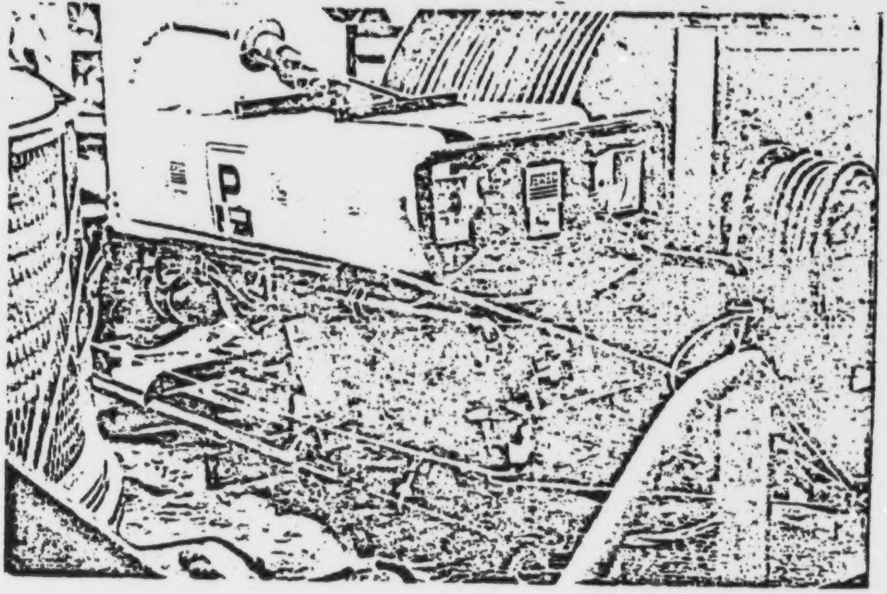


MANTIS 9 BEING LAUNCHED THROUGH MOONPOOL - INITIAL INVESTIGATION

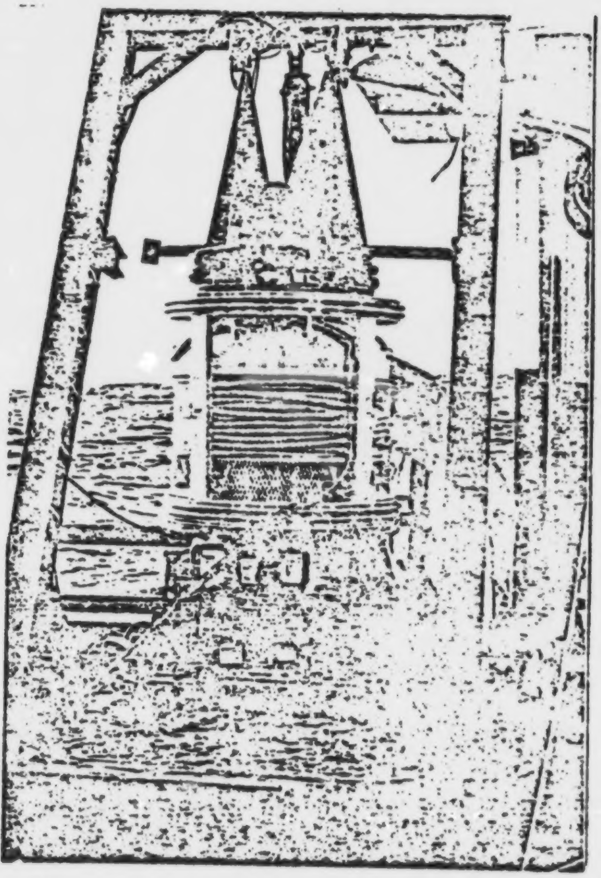
TUBE CONTAINING COLOUR SONAR CAN BE SEEN ON FAR SIDE



POLARIS V



RECON J - REMOTE CONTROL VEHICLE

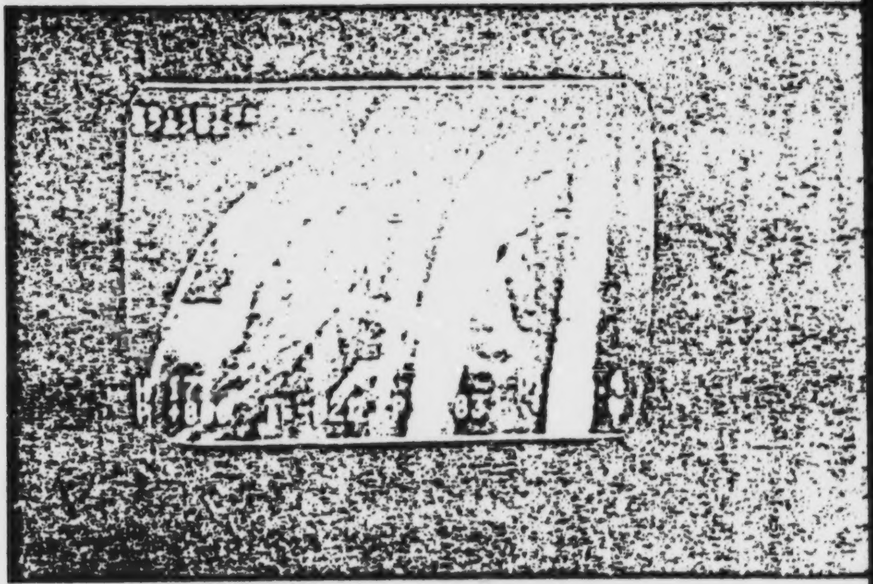


RCV WITH GARAGE ON LAUNCH STAND ADJACENT TO MOONPOOL

H 094
P +003
T -016
CP 0 07
D 203.2

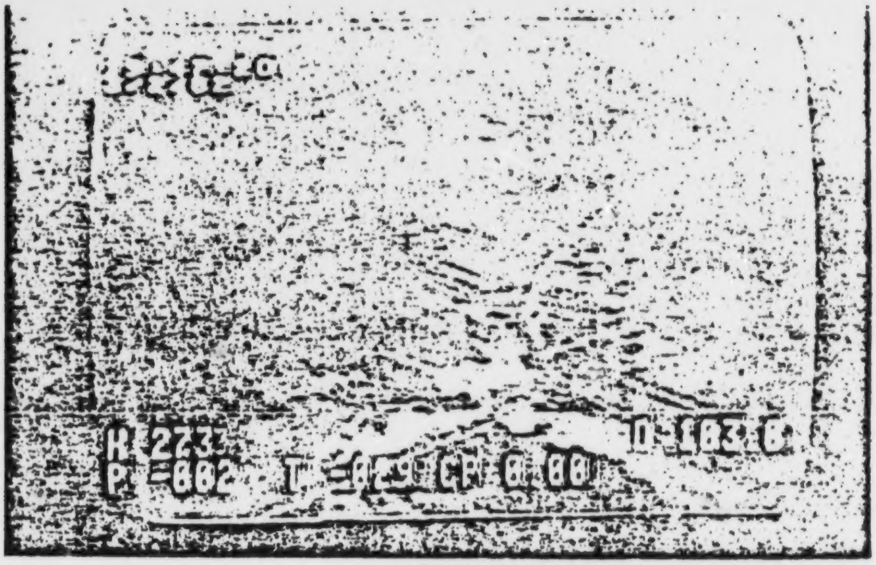
ROLLER FAIRLEAD

ROLLER FAIRLEAD



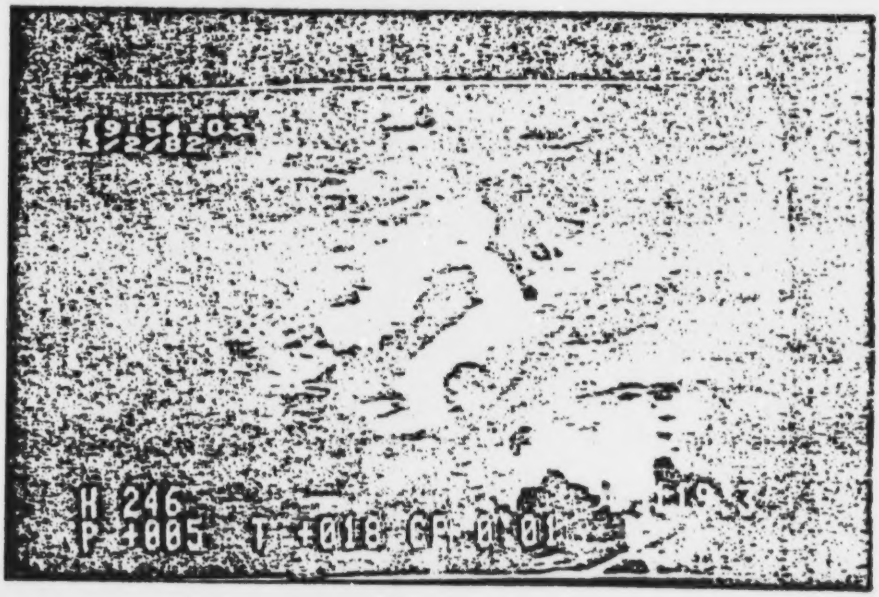
SCREEN INFORMATION

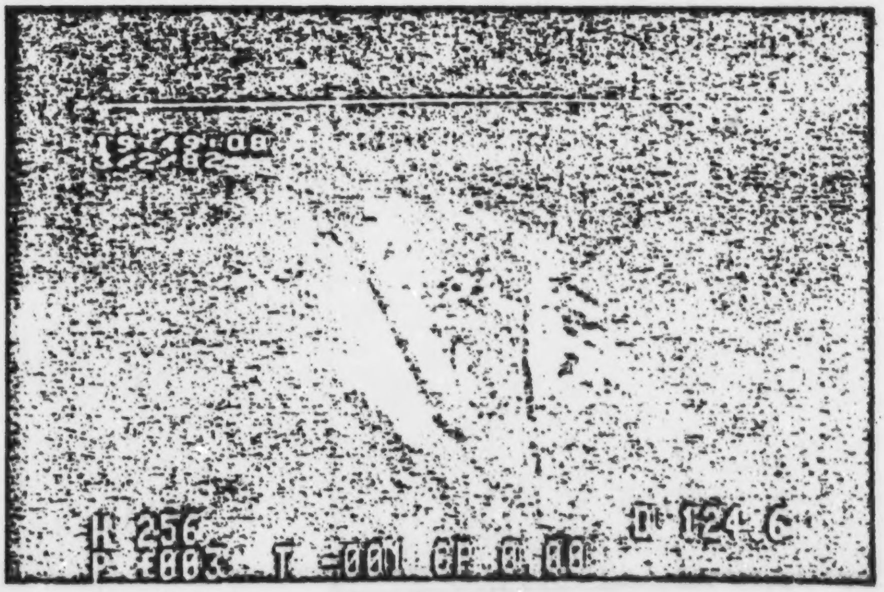
H = HEADING
D = DEPTH IN FEET
P = PAN OF CAMERA IN DEGREES - LEFT NEGATIVE
T = TILT OF CAMERA IN DEGREES - DOWN NEGATIVE
CP - CATHODIC PROTECTION PROBE - NOT IN USE - IGNORE


H 273
P -002 T -029 CP 0.00
D 183 C

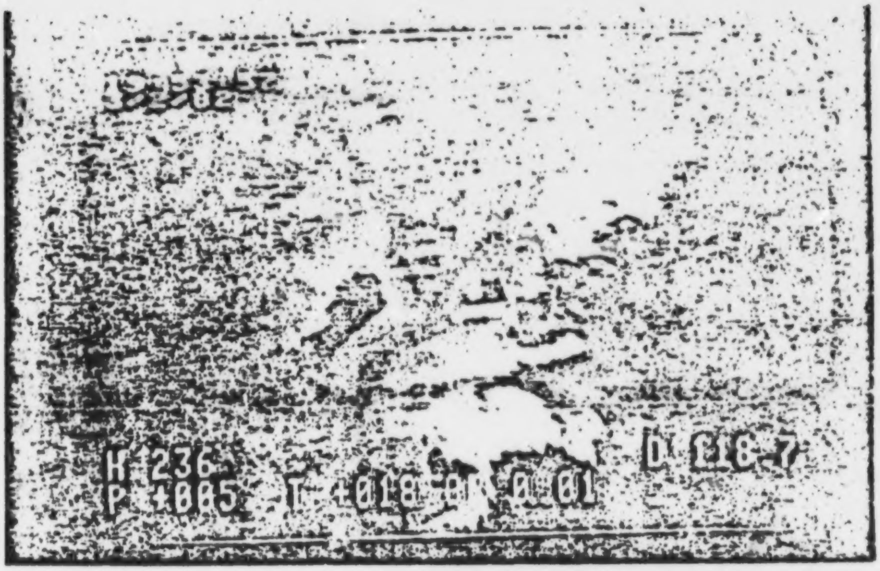
PORT PONTOON

DAMAGE TO PORT PONTOON


19:51:03
3/2/82
H 246
P +005 T +018 CP 0.01


19:49:08
3/2/82
H 256
P +003 T -001 CP 0.00
D 124 C

DAMAGE TO PORT PONTOON


H 236
P +085 T +018
D 118.7

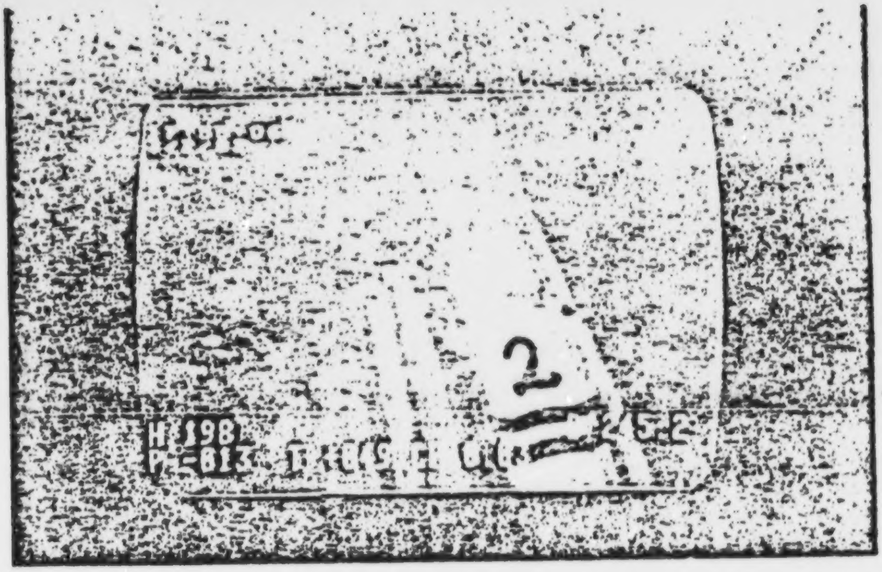
DAMAGE TO PORT PONTOON

202
-029 T +039 CP 0.08
D 129.4

DAMAGE TO PORT PONTOON

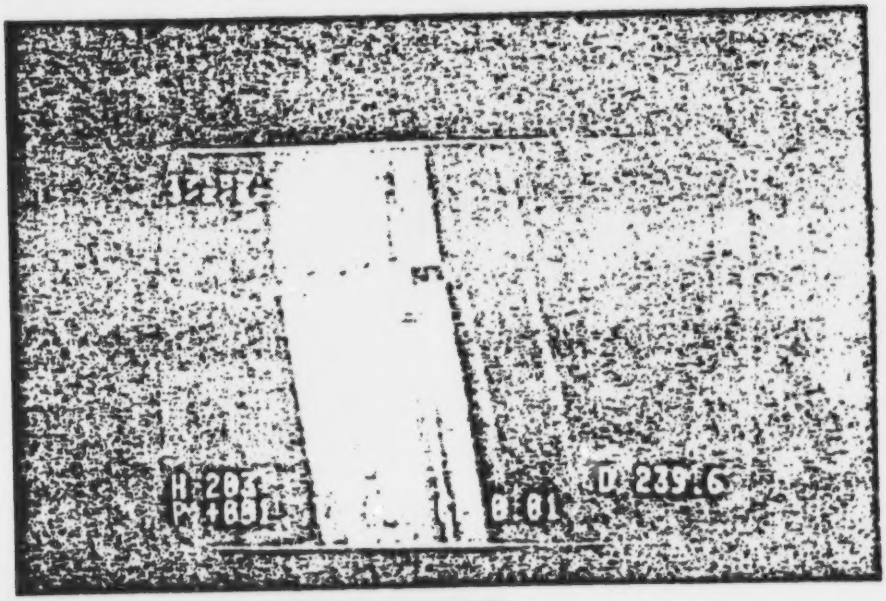
CP 0.02
D 110.5

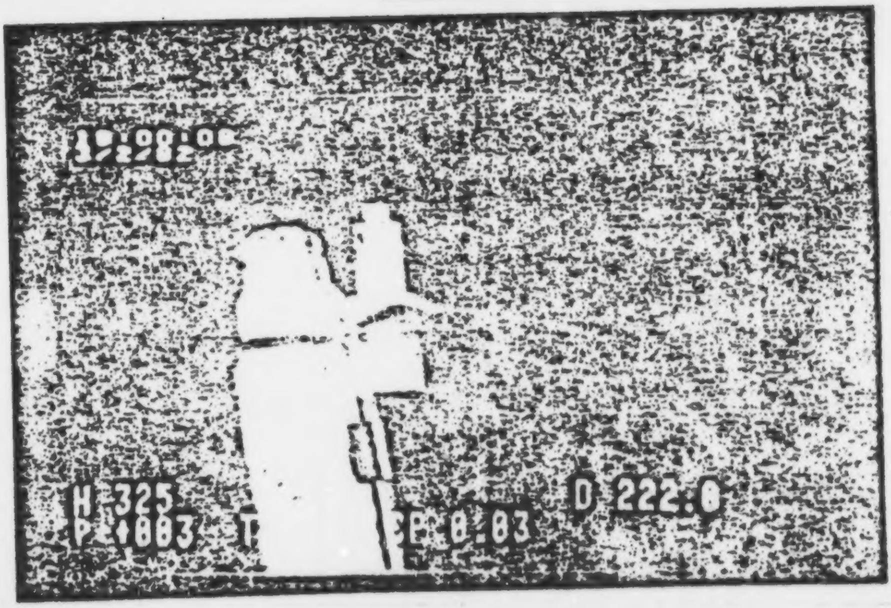
KEEL COOLERS



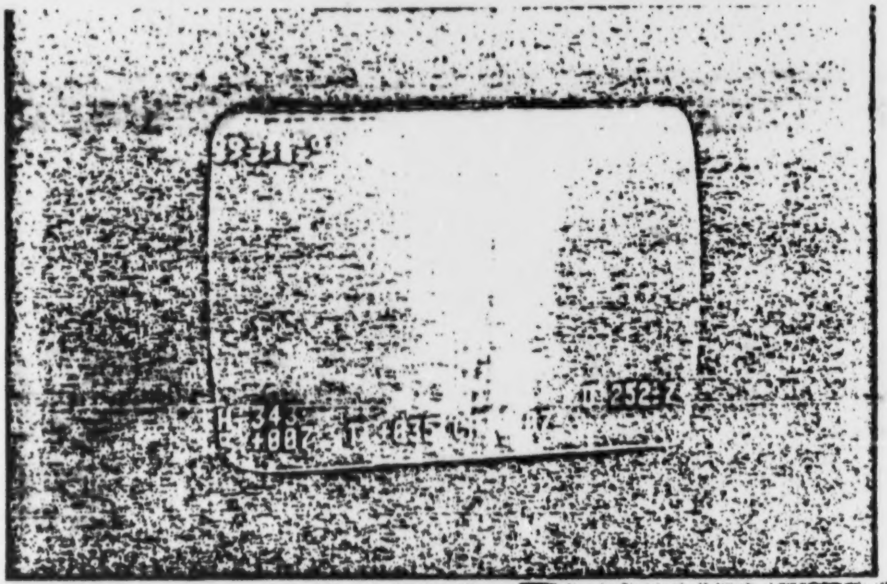
B.O.P. WELLHEAD

WELLHEAD - SHEAR RAMS

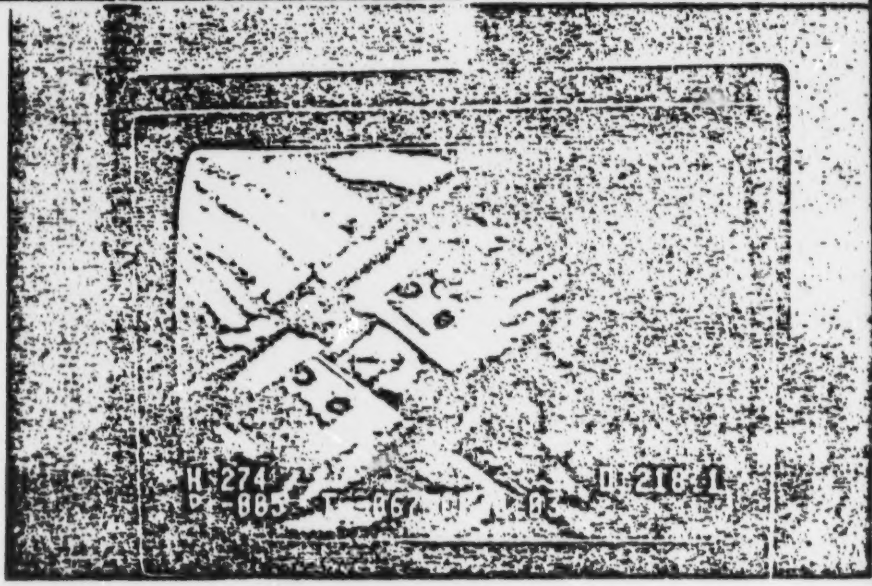



H 325
P +003
D 222.0
0.03

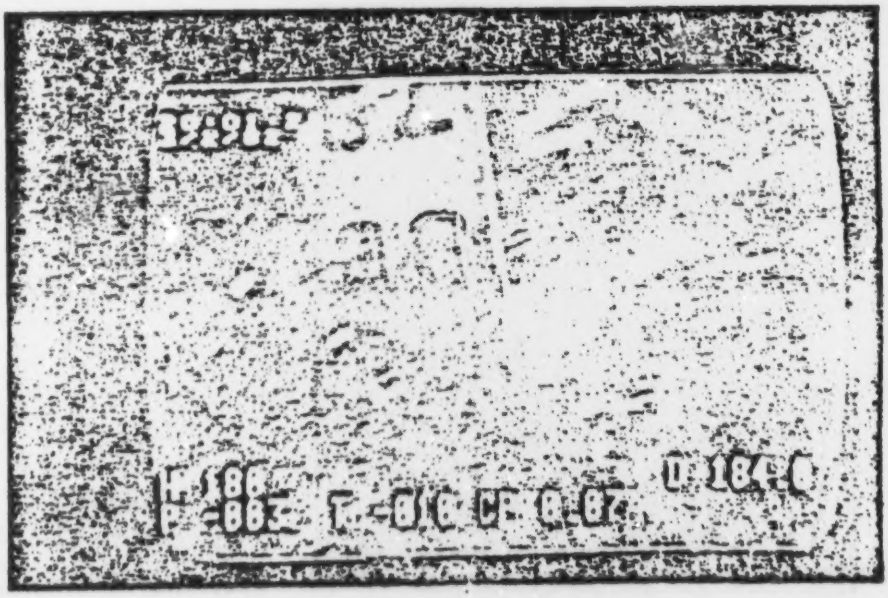
WELLHEAD N°2 LOCATER ARM WITH PINGER ATTACHED.



SECTION OF RISER PIPE



RISER PIPE CONNECTION



DRAUGHT MARKS AND LOAD LINE MARK

APPENDIX 2C

DIVING SURVEY

ROYAL COMMISSION ON THE OCEAN RANGER MARINE DISASTER

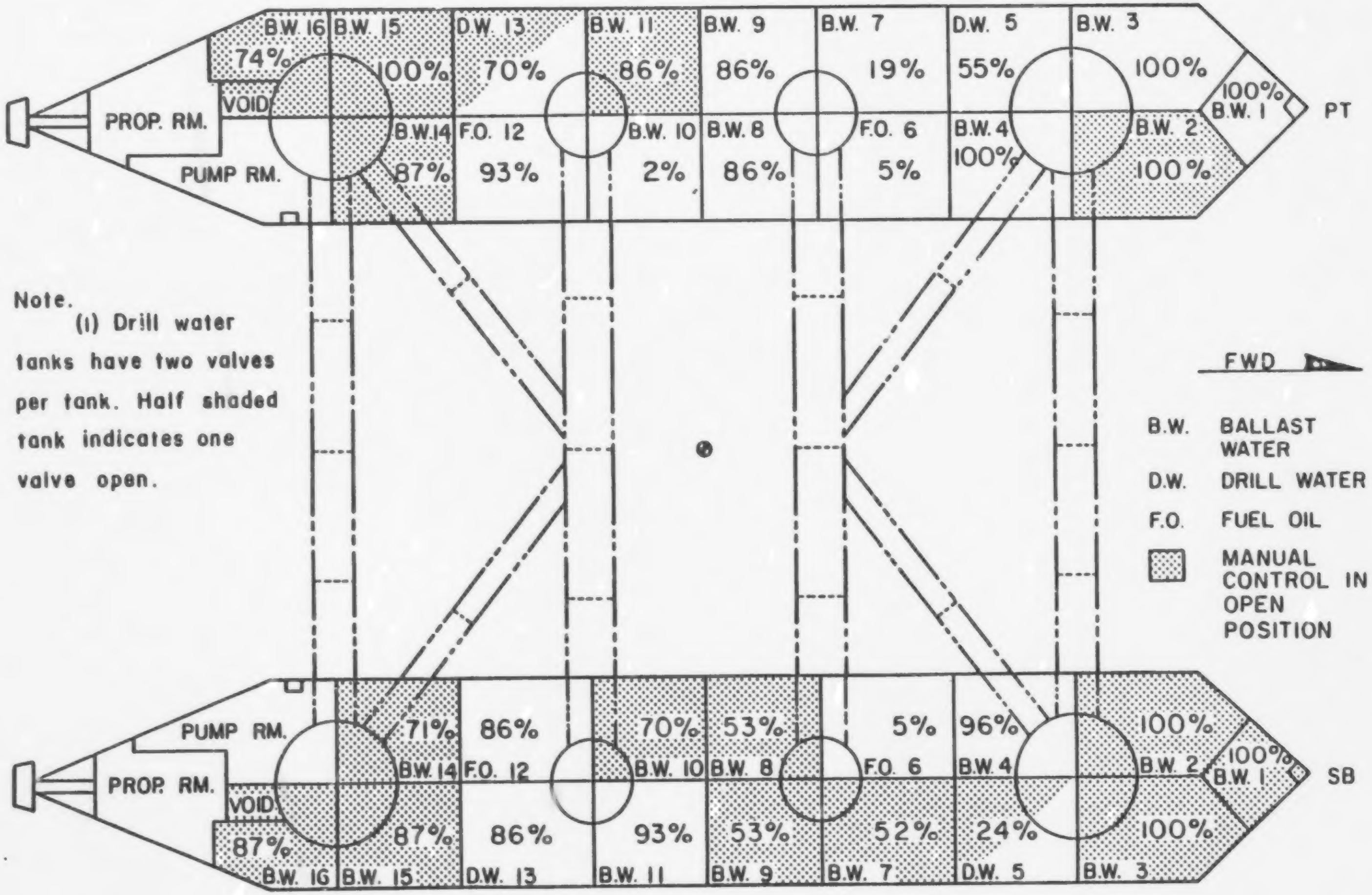
(SELECTED FINDINGS)

Contents of Pontoon Tanks (Long Tons)

Tank Number	Contents	Capacity	Feb. 14/a.m.		Dive		Dive (Minimum)		Solenoid Valves	
			Pt.	Stbd.	Pt.	Stbd.	Pt.	Stbd.	Pt.	Stbd.
1	Ballast	512.0	5.9	5.9					-	Open
2	Ballast	959.9	656.2	959.9	959.9	959.9	959.9	959.9	Open	Open
3	Ballast	959.9	959.9	959.9	959.9	959.9	959.9	959.9	D.C.	Open
4	Ballast	816.6	36.9	448.8	816.6	784.9	816.6	733.5	-	D.C.
5	Drill Water	797.9	83.8	98.2	466.8	207.5	403.7	138.7	-	1 Open/1 Closed (1 rod)
6	Fuel	667.6	107.3	26.4	18.3	19.8	0.0	0.0	N/A	N/A
7	Ballast	807.0	12.0	12.0	172.7	455.3	99.2	384.7	-	Open
8	Ballast	710.6	710.6	710.6	617.6	400.7	566.4	341.6	D.C.	Open
9	Ballast	710.6	710.7	710.7	617.7	399.9	566.5	340.7	D.C.	Open
10	Balllast	710.6	710.6	710.6	0.0	513.6	0.0	457.9	D.C.	Open
11	Ballast	710.7	710.7	710.7	618.0	666.6	566.9	618.0	Open	-
12	Fuel	667.6	175.5	236.9	626.2	580.3	580.4	532.4	N/A	N/A
13	Drill Water	787.2	494.5	282.1	568.2	787.2	506.7	787.2	1 Opn/ 1 Clsd (2 rods)	-
14	Ballast	816.6	554.2	465.2	717.0	604.0	661.7	544.0	Open	Open
15	Ballast	817.9	817.9	817.9	817.9	718.3	817.9	662.9	Open	Open
16	Ballast	347.5	347.5	347.5	282.5	315.4	259.2	293.9	Open	Open
	TOTAL	11,800.2	7094.2	7503.3	8259.3	8373.3	7765.0	7755.3		
			14597.5		16632.6		15520.3			

N.B. 1. Closed valve on STBD-5 indicated by video prior to salvage.
2. Valves No. S-26 possibly has dust cover on prior to salvage (per video).

Open: Manual Rod Holding Solenoid in Activated Position
N/A: Fuel Tanks Not Operated Remotely
D.C.: Dust Cover in Place
-: No Dust Cover or Rod


B.W. 16
74%
VOID
PROP. RM.
PUMP RM.
B.W. 15
100%
B.W.14
87%
D.W. 13
70%
F.O. 12
93%
B.W. 11
86%
B.W. 10
2%
B.W. 9
86%
B.W. 8
86%
B.W. 7
19%
F.O. 6
5%
D.W. 5
55%
B.W. 4
100%
B.W. 3
100%
B.W. 2
100%
100%
B.W. 1
PT
FWD
B.W. BALLAST WATER
D.W. DRILL WATER
F.O. FUEL OIL
▨ MANUAL CONTROL IN OPEN POSITION
PUMP RM.
PROP. RM.
VOID
87%
B.W. 16
71%
B.W. 14
87%
B.W. 15
86%
F.O. 12
86%
D.W. 13
70%
B.W. 10
93%
B.W. 11
53%
B.W. 8
53%
B.W. 9
5%
F.O. 6
52%
B.W. 7
96%
B.W. 4
24%
D.W. 5
100%
B.W. 2
100%
B.W. 3
100%
B.W. 1
SB

Note.
(1) Drill water tanks have two valves per tank. Half shaded tank indicates one valve open.

PRESENT LOWER HULL TANK SUMMARY

LIQUID LOADING/VALVE CONFIGURATION

APPENDIX 3

USCG EXHIBIT 43

REPORT ON THE STABILITY OF THE MODU OCEAN RANGER

Exhibit 43

27 MAY 1982

REPORT ON THE STABILITY OF THE MODU OCEAN RANGER

1. ABSTRACT

A study was made to determine how sensitive the stability of the rig was to changes in wind, loading, and mooring. The figures on the following pages address each of the tasks outlined by the Marine Board of Investigation. For clarity, each task statement is reiterated with pertinent observations. Conclusions have not been drawn in any case.

2. GENERAL OBSERVATIONS

The following observations apply to more than one figure.

a. Critical stability axis. The critical axis for intact stability is approximately along the 45° diagonal. The intact stability of a mobile offshore drilling unit is assessed based on the ratio of the righting energy of the rig to the heeling energy of the wind, up to the angle of downflooding. Although the equilibrium heel angle due to the wind overturning moment is less for the OCEAN RANGER when the wind is blowing along the 45° diagonal than it is for a beam wind, the righting energy/heeling energy ratio is also less, due in part to the lower downflooding angle. The net result is a more critical intact stability condition with a 45° diagonal wind.

b. In the assumed operating condition a relatively small shift in the transverse center of gravity, (TCG), or longitudinal center of gravity, (LCG), resulted in large heel or trim angles. A static list of 15 degrees was possible with a total shift of TCG or LCG of less than 1 foot. Mooring forces reduced this tendency to list.

c. Capsize due to the wind overturning moment was not indicated in any case.

d. Except for Task II, all righting moment and wind overturning moments were calculated ignoring the effect of the mooring lines. Actual righting moments including moorings were greater, as shown in Figure II. The actual wind overturning moments were less than those shown. As discussed in Section 5, the WINDHEEL computer program used in this analysis computes the overturning moments using the center of lateral resistance of the underwater area. Since the mooring fairleaders on the OCEAN RANGER were above the waterline, the calculated moment arm between the center of wind pressure and the center of resistance is higher than the actual arm.

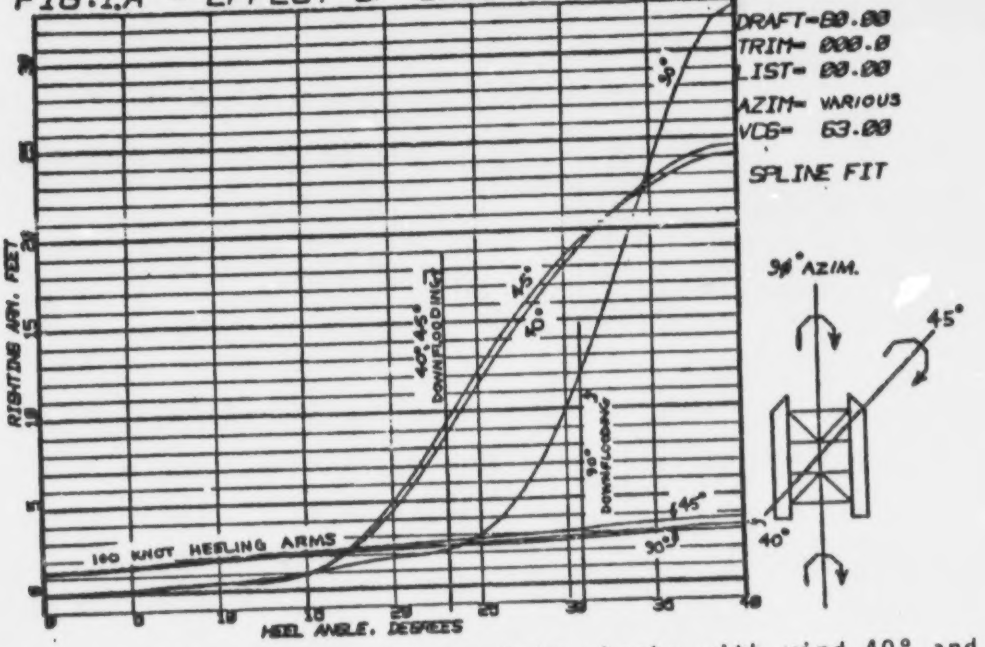
e. Lift forces on the upper hull underside were negligible. At a 20° heel angle, lifting reduced the overturning moment by approximately 5%.

3. RESULTS

Figures I.A - VIII Show the results for each task.

Note: Task III was deleted by Marine Board Memo dated 8 March 1982.

FIG.I.A - EFFECT OF INCIDENT WIND AZIMUTH



Task I.a - Vary wind direction. Make checks with wind 40° and 90° off the port bow.

Observations:

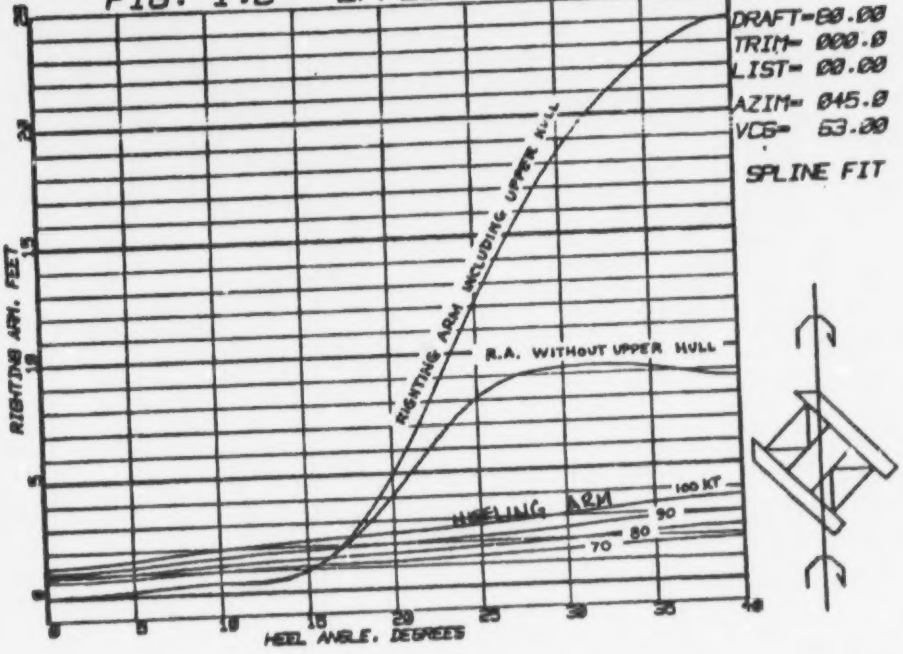
(1) As discussed in Section 2, the 45° azimuth is critical. Pure rotation about this axis is not an equilibrim condition for the unrestrained rig. If the rig was rotated about the 45° axis without restraint, it would trim longitudinally to an even keel condition with a static inclination about the centerline, which is the axis of minimum righting energy. Under the influence of a steady wind, the rig would shift its heading to a corresponding beam wind condition. However, the OCEAN RANGER was restrained from appreciable changes in heading angle by its moorings. Additionally, the wind loads in the longitudinal and transverse directions are approximately equal for this rig with a wind along the 45° diagonal, providing further restraint. The assumption of pure rotation about the 45° axis is therefore justified in this case.

(2) The wind overturning moment is affected little by changes in wind azimuth from 40° to 90° off the beam. The static list angle was about 38% greater for the beam wind condition, (90° azimuth), than for the 45° diagonal wind.

(3) Since the 45° axis was the critical stability axis, it was used throughout this study in lieu of the 40° axis originally specified by the Marine Board. The 40° and 45° diagonal righting arms shown indicate rotation down by the starboard quarter.

(4) The resultant static list angle along the 45° diagonal is 17.5 degrees.

FIG. I.B - EFFECT OF WIND SPEED



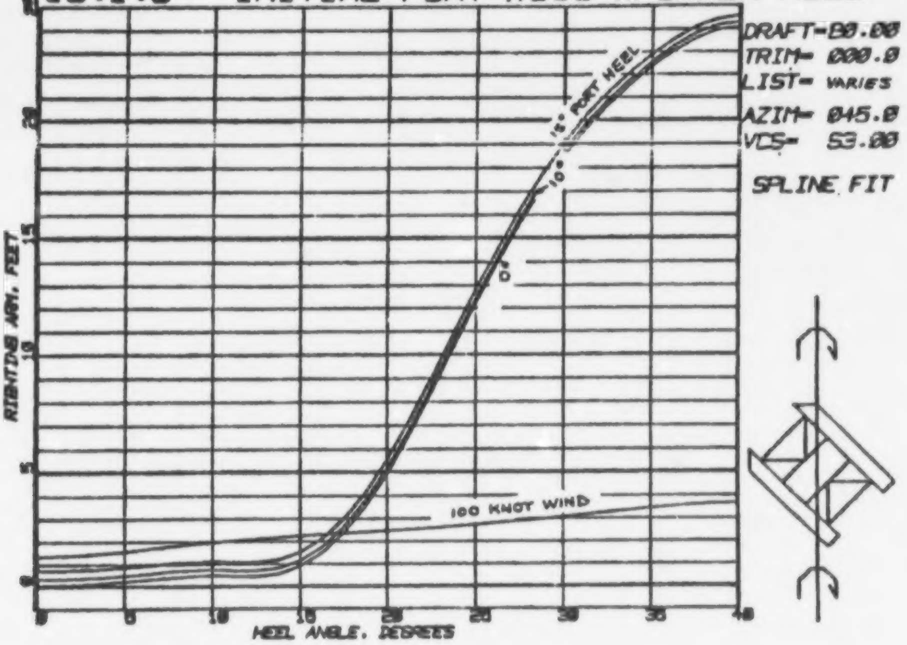
Task I.b - Vary wind speed.

Observations:

(1) Wind was from 45° off the port bow.

(2) Increasing the wind speed from 70 to 100 knots resulted in a 2° increase in static list along the 45° diagonal.

FIG.I.C INITIAL PORT HEEL W/UPPER HULL



Task I.c - Port heel. Righting arms were calculated for the 45° diagonal with an initial port heel of 0°, 10°, and 15°.

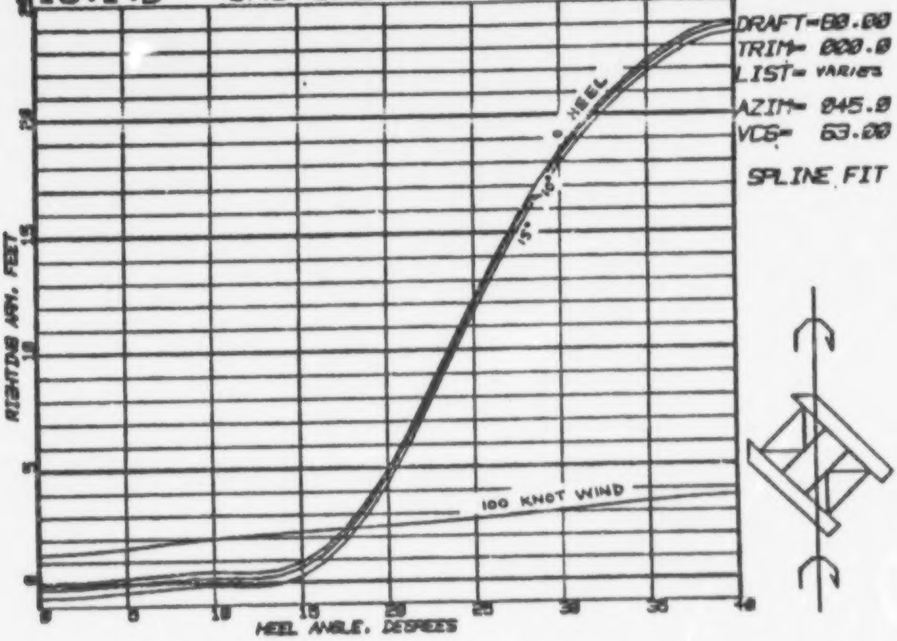
Observations:

(1) Wind is from 45° off the port bow.

(2) Righting arms are positive with rotation down by the starboard quarter.

(3) Upper hull considered fully buoyant.

FIG. I.D INITIAL STBD HEEL W/UPPER HULL



Task I.d - Starboard heel. Righting arms were calculated for the 45° diagonal with an initial starboard heel of 0°, 10°, and 15°.

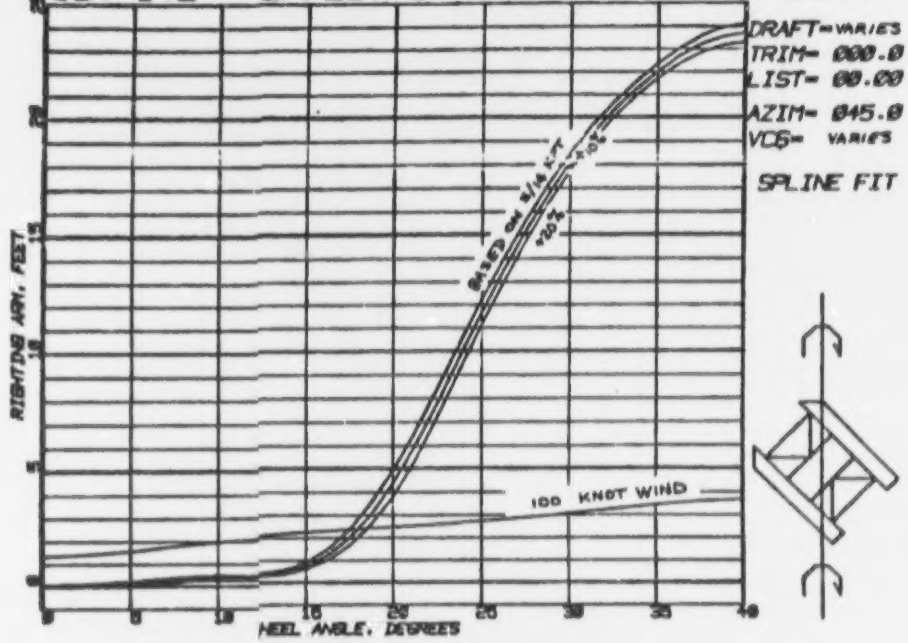
Observations:

(1) Wind is from 45° off the port bow.

(2) Righting arms are positive with rotation down by the starboard quarter.

(3) Upper hull considered fully buoyant.

FIG. I.E - EFFECT OF INCREASED DECK LOAD



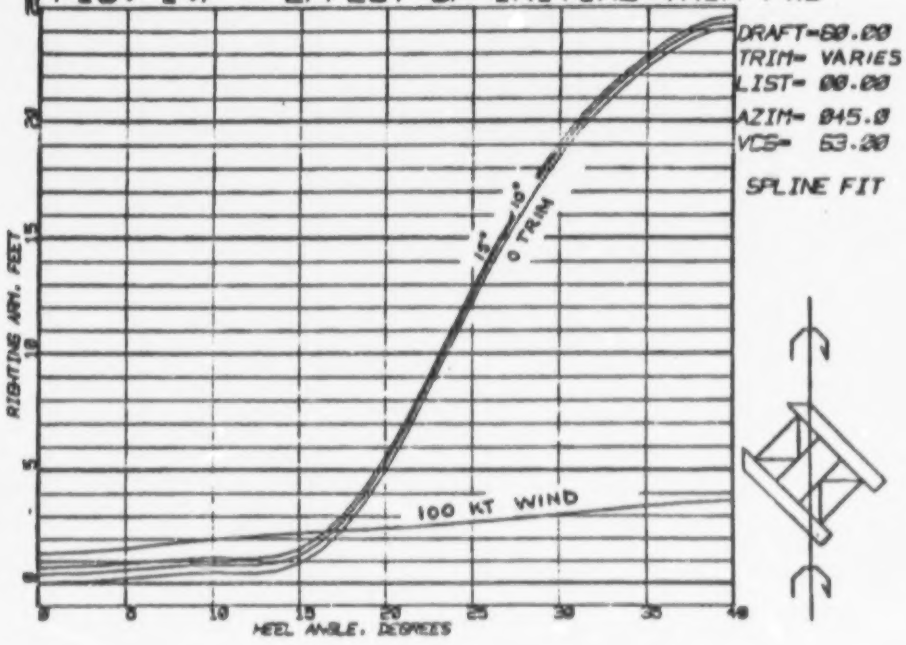
Task I.e - Deck load increase. Determine righting arms with deck load increased by 10 and 20 percent.

Observations:

(1) A 20% increase in deck load above that shown on the 2/14/82 morning report resulted in an additional 1.5 degrees in static list on the 45° diagonal under the influence of a 100 knot wind from the port bow.

(2) See Section 4 for a discussion of the assumed loading condition.

FIG. I.F - EFFECT OF INITIAL TRIM FWD

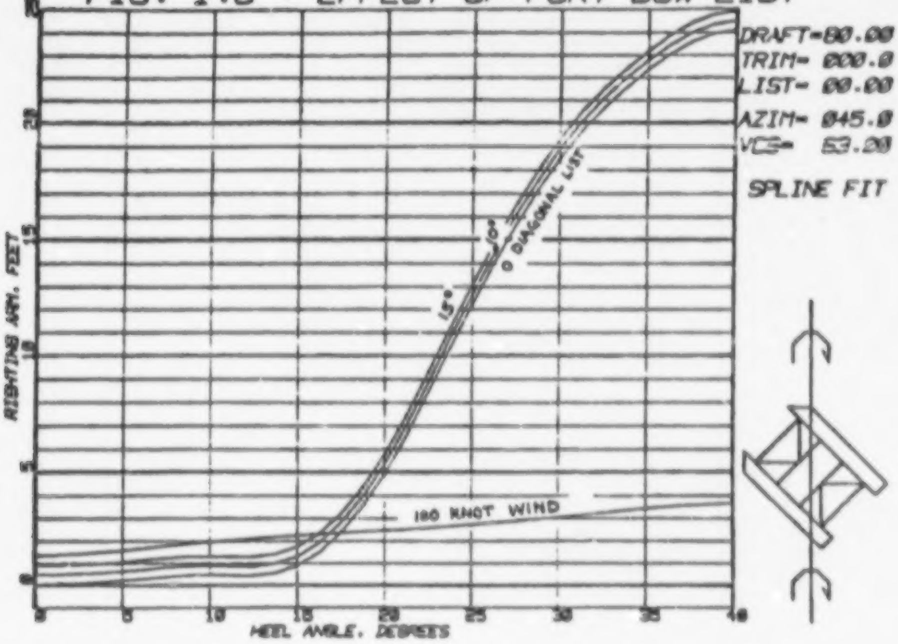


Task I.f - Trim by the bow. Righting arms were calculated for the 45° diagonal with an initial trim of 0°, 10°, and 15° down by the bow.

Observations:

(1) Righting arms shown are positive with rotation down by the starboard quarter.

FIG. I.G - EFFECT OF PORT BOW LIST

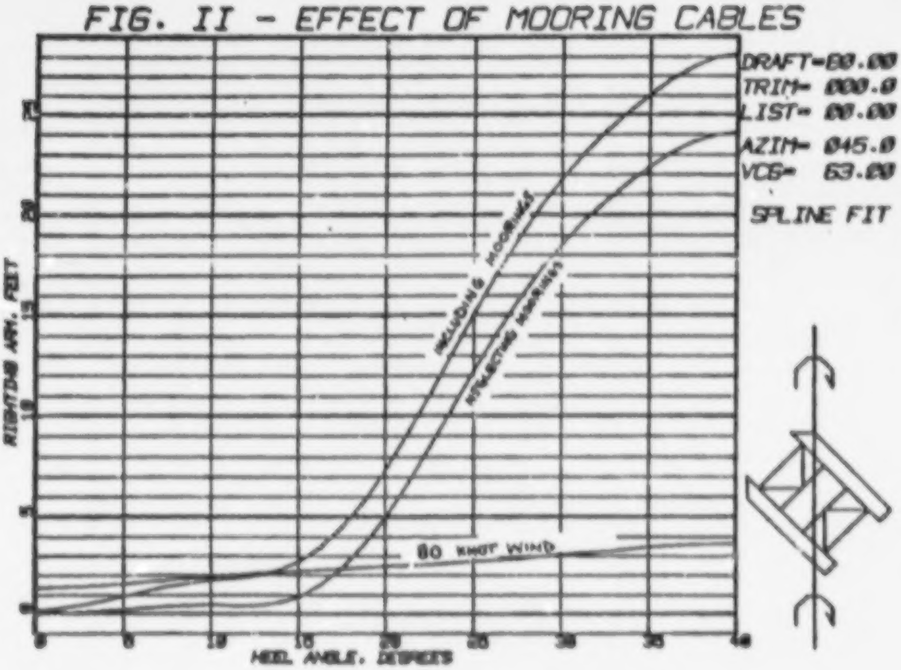


Task I.g - Diagonal list. Calculate righting arms with an initial list down by the port bow of 10° and 15°.

Observations:

(1) Rotation shown is down by the starboard quarter.

FIG. II - EFFECT OF MOORING CABLES



Task II - Effect of mooring system.

Observations:

(1) Rotation is down by the starboard quarter under the influence of an 80 knot wind from 45° off the port bow.

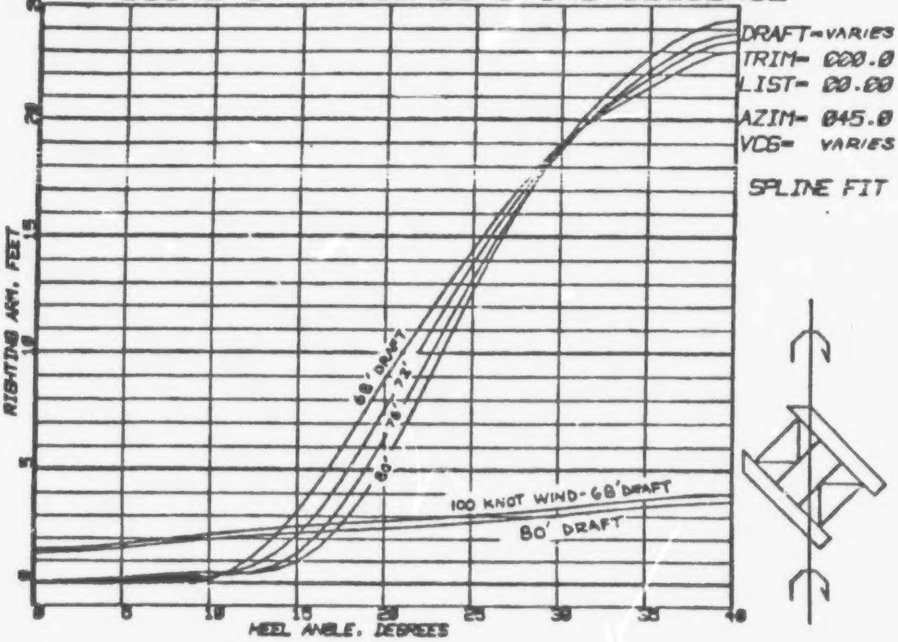
(2) The wind heeling arms shown are higher than actual values. The lateral center of resistance of the underwater body was used in lieu of the mooring attachment point in determining the overturning moment arm. See Section 2d.

(3) Mooring line tensions were calculated assuming a steady 80 knot wind, 30 foot significant wave height (58 foot maximum wave) and 1.0 knot current all acting from 45° off the port bow. Changes in catenary and tension were calculated based on pure rotation about the heel axis with these loads superimposed. See Section 4 for further discussion.

(4) Righting moments from the mooring pull-down had their greatest effect at low heel angles.

(5) The maximum calculated mooring line tension was less than 1/2 the breaking strength. The actual line tensions were much higher. This analysis neglected the additional mooring load due to increased wind overturning moment and lateral drag at large heel angles.

FIGURE IV - DEBALLASTING SEQUENCE



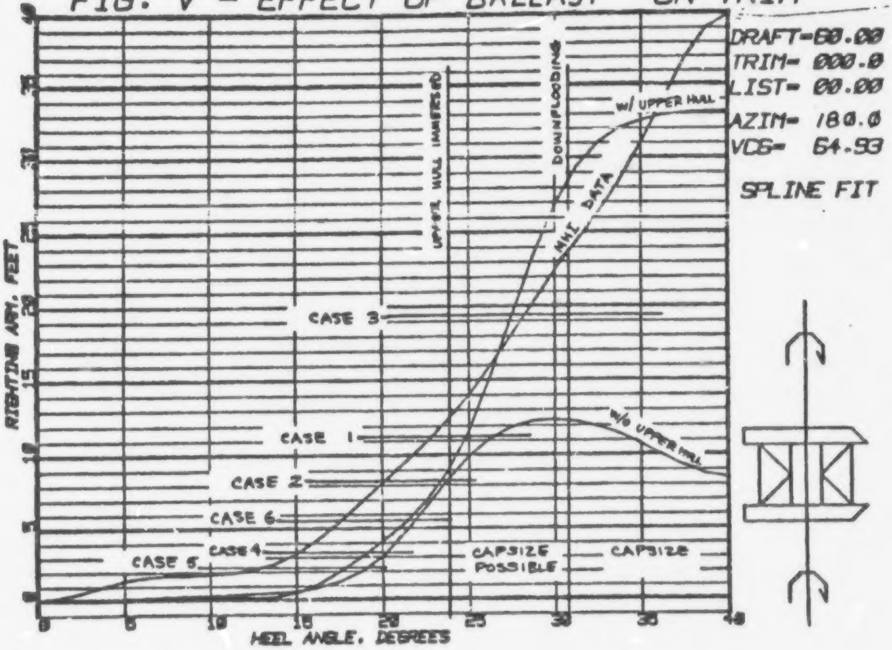
Task IV - Deballasting. Determine righting arms and wind heeling arms for various drafts as the unit is deballasted from the 80' drilling draft toward the survival draft. Use the operating manual deballasting sequence and investigate at 4 foot increments between 80 foot and 68 foot drafts.

Observations:

(1) Deballasting was assumed from tanks PT-8, ST-8, PT-10, and ST-10. No other weight removal or relocation was assumed. These curves therefore should represent the worst case. The initial loading is described in Section 4. At the 68 foot draft, approximately 16% remained in the four deballasted tanks, all of which were initially full.

(2) As the deballasting sequence progressed, the rig became more sensitive at heel angles less than 10°. Conversely, it became more stable in the range from 10°-30°, showing a reduced equilibrium heel angle under the influence of a 100 knot wind from the port bow.

FIG. V - EFFECT OF BALLAST ON TRIM



Mitsubishi
Reference 17

Task V - Effect of Ballast Shifting on Trim

a. The assumed loading condition for 14 February, discussed in Section 4, was used as a starting point. The starting ballast configuration is shown in Figure 1. Two ballast shifting scenarios were studied. In the first, Cases 1-3, ballast was shifted from after-most to forward-most tanks. The final condition for this "extreme ballast shift" represented filling the ballast tanks in order from bow to stern, with no increase in the total ballast aboard. Case 1 was such a shift of port hull ballast only, Case 2 was starboard hull ballast only, and Case 3 was ballast in both hulls.

b. The second shifting scenario assumed a reasonable deballasting sequence was attempted, but the ballast water was shifted to empty forward tanks rather than overboard. The four center tanks in each lower hull, Nos. 8 through 11 were emptied and their contents shifted as far forward as possible. Case 4 was such a shift for the port hull ballast only, Case 5 was starboard hull ballast only, and Case 6 was ballast in both hulls.

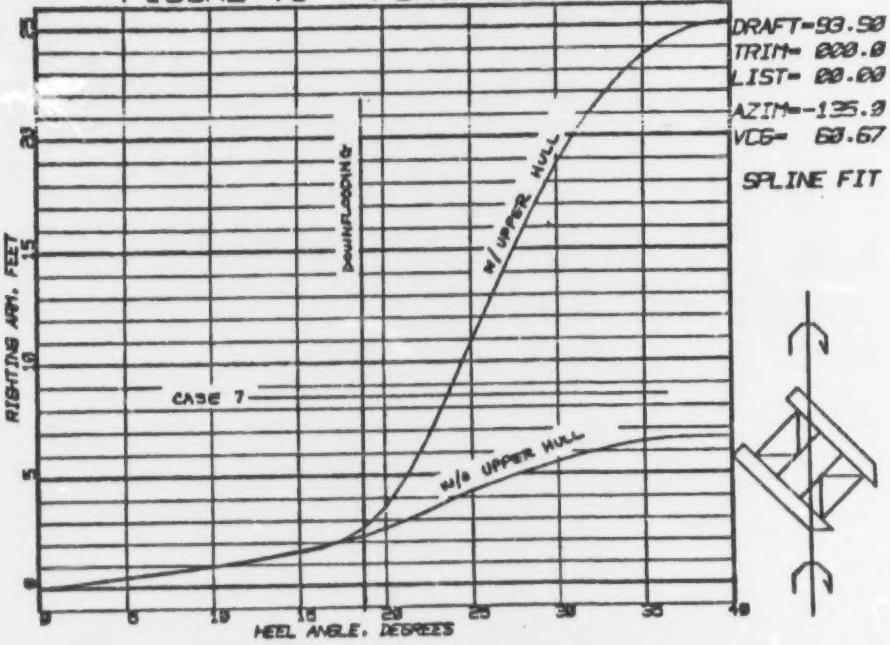
c. Because ballast was shifted entirely in the forward direction, only pure rotation down by the bow resulted. Since no ballast was added or removed, there was no draft change. All cases assumed a still water condition. Wind, wave and mooring forces were not considered. At 23.8° the lower edge of the upper hull was immersed. At 31° downflooding began through the hawse pipe openings on the main deck.

(continued)

Task V - Effect of Ballast Shifting on Trim (continued)

d. In all cases except those involving an "extreme ballast shift" of the port hull ballast, (Cases 1 and 3), the rig came to rest with the upper hull clear of the water. In Cases 1 and 3 the watertight integrity of the partially immersed upper hull became important since its reserve buoyancy was necessary to prevent further inclination down by the bow. In these cases, capsize was considered possible since the actual wind and sea conditions could cause downflooding and further inclination. In case 3, the watertight integrity of the upper hull was required to prevent capsizing.

FIGURE VI - PORT HULL FLOODING



Task VI - Effect of Port Hull Flooding

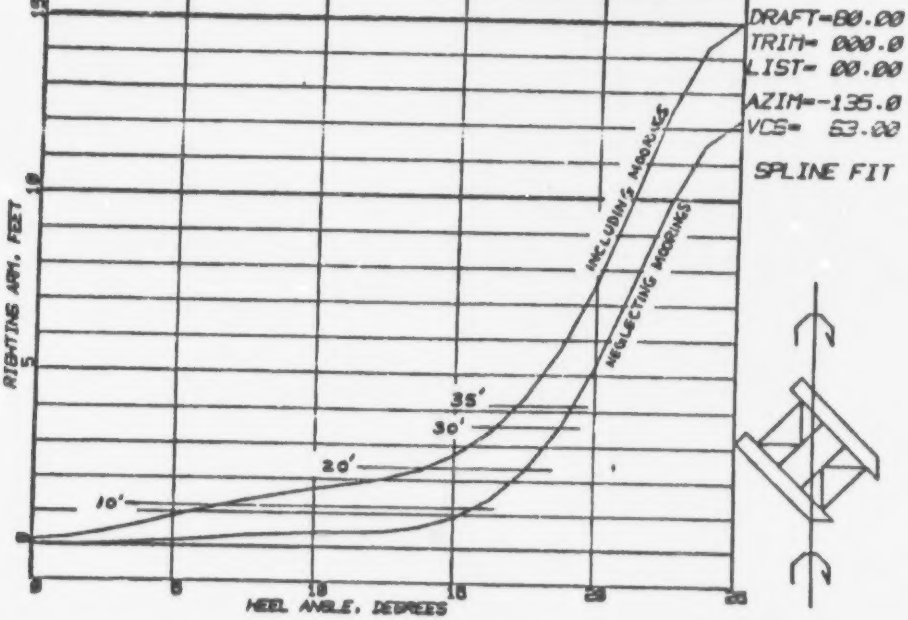
a. The assumed loading condition for 14 February, discussed in Section 4, was used as a starting point. The ballast configuration of the lower hulls is shown in Figure 1. Flooding was assumed in all empty ballast tanks in the port lower hull. Rotation down by the port bow resulted with a mean draft increase at the longitudinal center of flotation (LCF) to 93.9 feet. Because of the draft increase, the downflooding angle to the hawse pipe openings was reduced to 18.7°.

b. After flooding, the rig came to rest with a list of 23.5° down by the port bow. In this condition, the hawse pipe openings on the port forward column were immersed by 17 feet. Downflooding to the chain lockers occured, resulting in an increase to 26° list, down by the port bow.

c. In this condition all reserve buoyance was contained in the upper hull. If the upper hull was not maintained watertight, capsize would result.

d. This study assumed a still-water condition. Wind, wave and mooring forces were not considered.

FIG. VII - EFFECT OF CHAIN LKR FLOODING



Task VII - Effect of Chain Locker Flooding

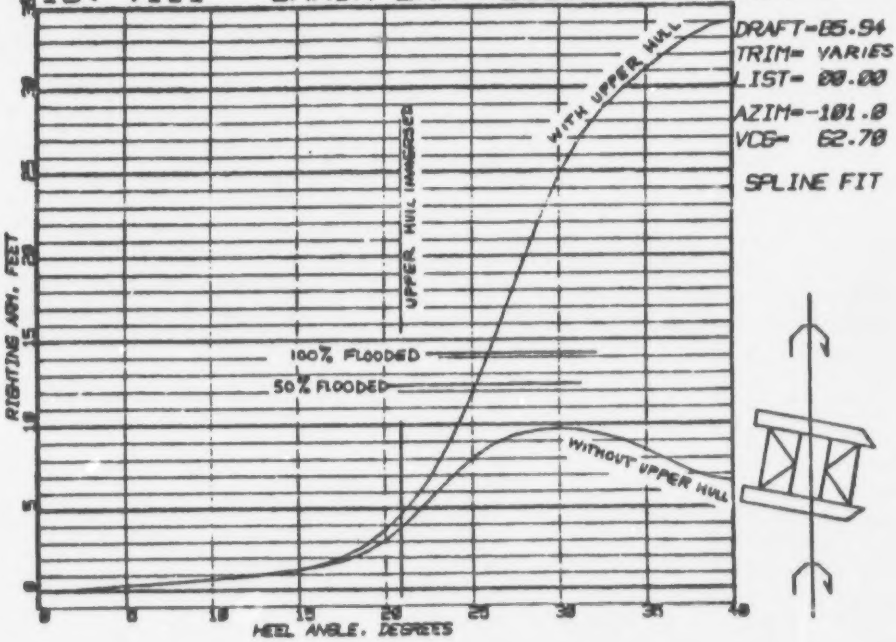
a. The port forward column chain lockers were assumed to flood. The resultant list along a 45° diagonal axis is shown above for various flooding levels. Rotation is down by the port bow.

b. The combined capacity of the three chain lockers in each column is :

Flooding Level	Long Tons, S.W.	Gallons
5'	154	40,320
10'	308	80,640
15'	462	120,970
20'	615	161,030
25'	769	201,350
30'	923	241,670
100% - 35'	1077	282,000

c. Assuming the hawse pipes serving each chain locker are 12" in diameter, a 5 foot head of water over their openings would allow about 150 gallons/second of inflow. The chain lockers would fill up at a rate of about 1 foot per minute of submersion under a 5 foot head.

FIG. VIII - CHAIN LKR FLOODING W/TASK V.



Task VIII-Chain locker flooding combined with Case 1 of Task V.

a. The "extreme ballast shift" of Case 1, Task V was assumed as a starting point. This corresponds to shifting all the ballast in the port lower hull as far forward as possible. Downflooding to the port forward chain lockers was then assumed as a result of green water over the hawse pipe openings. The curves above represent still water conditions. Wind, wave and current forces were not considered.

b. The results indicate rotation down by the port bow along an axis 11° off the centerline with the three port forward chain lockers flooded to 100% of their capacity. For the 50% flooded condition, rotation is closer to pure trim, and the righting arms are slightly higher than those shown above.

c. With the port forward chain lockers 100% flooded and all ballast in the port hull shifted as far forward as possible, the rig came to rest down by the port bow along an axis 11° off the centerline with a static list of 26°. With the chain lockers 50% flooded and the same ballast shift, the static list was reduce to approximately 25°. At 21° the lower edge of the upper hull was immersed. In both the 50% and 100% flooding cases, the watertight integrity of the upper hull was necessary to prevent capsizing.

d. The righting arms of the rig decrease with increasing draft. As a result, the 100% flooded condition shown above is a worst case. The effect of ballast shifting with no chain locker flooding is shown in Figure V.

4. SUMMARY OF ASSUMPTIONS

a. Loading Condition. The liquid loading of the lower hull shown in the weekly stability report of 9 February, reference 1, was assumed. See Figure 1. The morning reports for 9-14 February were studied to arrive at an assumed KG of 63.0 feet. This corresponds to the drilling condition with riser suspended and 12 anchors deployed, each with 4035 feet of cable and 1650 feet of chain outboard of the fairleader. Small changes (plus or minus 2 feet) in KG had little effect on the righting arms for heel angles greater than 5 degrees.

b. Wave and current loads were not considered except during the mooring load analysis.

c. Downflooding was considered to occur when the upper end of the hawse pipes at the 151.5 foot elevation were submerged. The total displaced volume of the chain lockers in each column is approximately 1080 long tons.

d. Cargo and equipment shifting at large angles of heel was not considered.

e. Throughout this report the terms heel, list and trim are defined in offshore drilling industry terms. Heel is a static inclination about the centerline, trim is static inclination down by either the bow or stern and list is a static inclination about any other axis, i.e. - a combination of heel and trim.

f. Two hull models were developed to compute righting arms. The first included the upper hull between the 130 foot and 151.5 foot levels. The second ignored the upper hull entirely. A comparison is shown in Figure I.B.

g. The mooring loads in Task II were calculated based on the OCEAN RANGER's Operating Manual, reference 9. The loading information in references 1 and 2 was used to determine the catenary length, fairleader angle and pretension. From this data the mooring pull-down and catenary tension loads were computed. The high line tension was calculated for the assumed environmental conditions, (see Figure II), using ODECO's charts in the Operating Manual and the explanation of their derivation in references 4-8. The righting moment due to the modified pull-down and line tension loads was then computed as a function of the heel angle. Pure rotation about the 45° diagonal axis was assumed. The calculated high line tension was assumed in the three upwind mooring lines. No additional mooring load was calculated to account for the added lateral drag load as the list angle increased. As a result, the calculated line tensions were lower than actual.

5. COMPUTER PROGRAMS USED

The following are brief descriptions of computer programs used in this analysis.

a. STAAF (Stability Analysis of Arbitrary Forms). Developed by CADCOM, Inc., 1976. This program has options to compute hydrostatic properties and righting arms about any heel axis. The input is offset half-breadths and heights at longitudinally-spaced transverse sections. A trapezoidal integration scheme was used for both station areas and longitudinal integration.

STAAF Anomalies:

(1) Input by station offsets makes it impossible to describe circular cylinders such as columns and truss members exactly. Equivalent rectangular or polygonal cylinders must be used with similar waterplane area and inertia characteristics. Differences in output are negligible.

(2) When a heel axis other than the centerline is described, longitudinal equilibrium is not satisfied. The draft alone is varied for displacement equilibrium. The righting arms may not be representative of the lowest energy condition of the vessel for all types of overturning moments. However, if the unit is constrained to rotate about the non-equilibrium axis by moorings or wind loading, STAAF correctly models the physical conditions. This was the case with the OCEAN RANGER. See the discussion of Figure I.A.

(3) Initial heel normal to the trim axis cannot be input. Consequently, it was impossible to model directly righting arms taken about a 45° diagonal when an initial heel to port or starboard was specified. A separate program was developed for this report to account for the initial TCG offset.

b. WINDHEEL. Developed by 8th Coast Guard District (mmt). A three-dimensional image of the rig is input by directly digitizing profile and plan views. For any combination of draft and trim, initial list, wind azimuth angle (heel axis orientation) and heel angle, the wind overturning moment is calculated. The total moment is calculated by summing the wind pressure drag moments on each component area. The lateral center of resistance is calculated as the centroid of the projected underwater area. A point-to-point integration scheme is used to compute exactly the centroid and area of each projected component area. A full graphic image of the unit is generated for visual verification, as shown in Figure 2.

WINDHEEL Anomalies:

(1) Shielding is not considered. The rig is transparent to the incident wind; therefore downwind areas are not affected by upwind areas. This approximation is only slightly conservative, since the columns and bracing, derrick, and upper hull sides and bottom, which account for 30 % of the total overturning moment, are in reality affected little by the presence of other areas.

(2) Lift forces are ignored. Only lateral drag forces and moments are computed. Lift forces on the upper hull underside reduces the overturning arm by approximately 5% at a heel angle of 20°.

(3) Because the program is based on the existing USCG drill rig stability criteria, the rig is assumed to be drifting downwind and heeling under the influence of the wind. The lateral center of resistance of the underwater projected area is used to find the overturning arm for each area. As discussed in Section 2d., in the case where a rig is moored with above-water fairleaders, such as the OCEAN RANGER, this arm would be less.

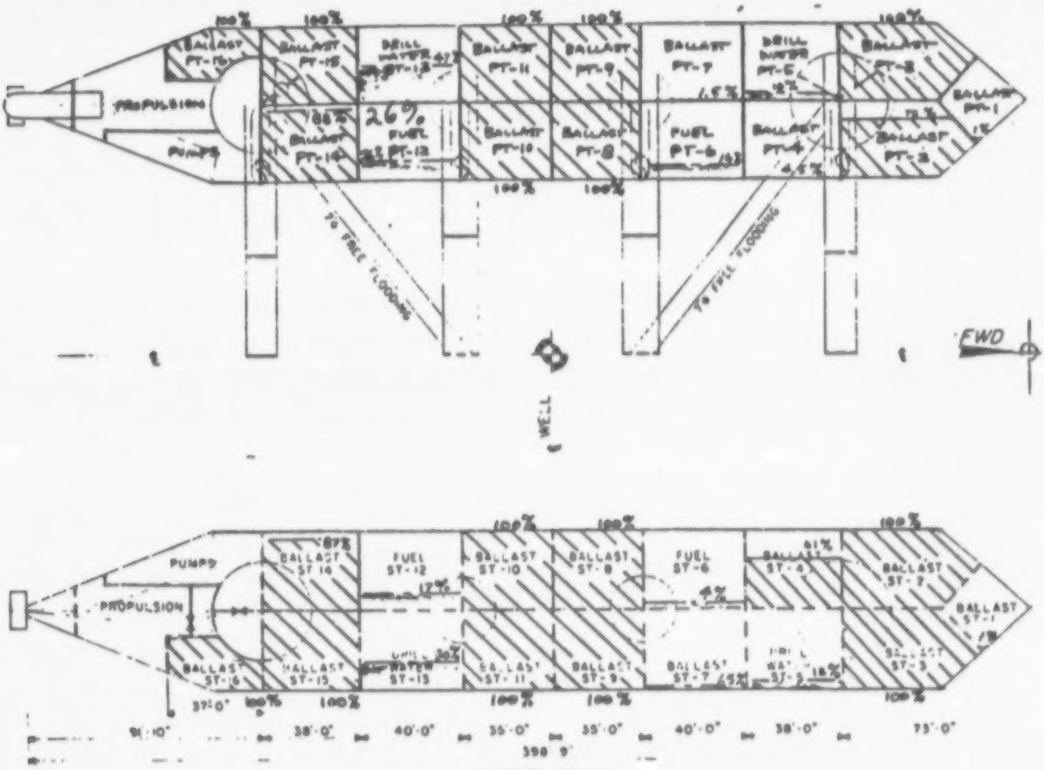

100%
BALLAST PT-16
BALLAST PT-15
DRILL WATER PT-13
47%
BALLAST PT-11
BALLAST PT-9
BALLAST PT-7
DRILL WATER PT-5
BALLAST PT-3
BALLAST PT-1
PROPULSION
PUMPS
86%
26%
FUEL PT-12
BALLAST PT-14
BALLAST PT-10
BALLAST PT-8
FUEL PT-6
BALLAST PT-4
BALLAST PT-2
1.5%
13%
4.5%
TO FREE FLOODING
TO FULL FLOODING
FWD
WELL
PUMPS
PROPULSION
BALLAST ST-14
87%
FUEL ST-12
17%
BALLAST ST-10
BALLAST ST-8
FUEL ST-6
4%
BALLAST ST-4
61%
BALLAST ST-2
BALLAST ST-1
BALLAST ST-16
BALLAST ST-15
DRILL WATER ST-13
30%
BALLAST ST-11
BALLAST ST-9
BALLAST ST-7
4.5%
DRILL WATER ST-5
18%
BALLAST ST-3
37'-0"
91'-10"
38'-0"
40'-0"
35'-0"
35'-0"
40'-0"
38'-0"
75'-0"
398'-9"

FIGURE 1

2/9/82 BALLAST CONFIGURATION

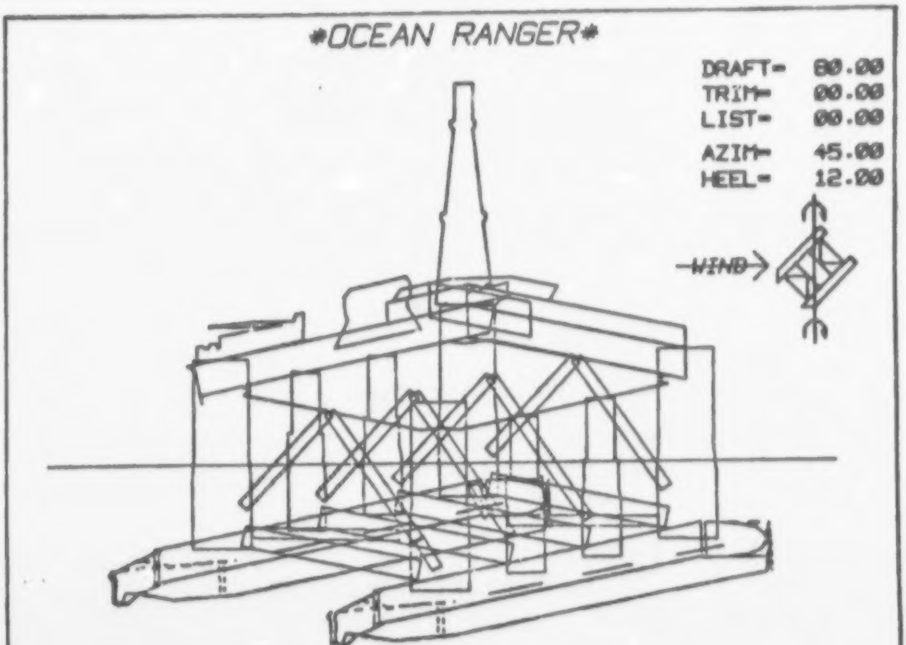

OCEAN RANGER
DRAFT= 80.00
TRIM= 00.00
LIST= 00.00
AZIM= 45.00
HEEL= 12.00
WIND

FIGURE 2

6. REFERENCES

1. Weekly Stability Report of MODU OCEAN RANGER dated 9 February 1982

2. Morning Reports of MODU OCEAN RANGER dated 9-14 February 1982

3. Korkut, M. D. and Hebert, E. J. "Presenting in Condensed, Usable Form Equations to Find Anchor Chain Curve", OCEAN INDUSTRY

4. Childers, M. A. "Mooring Systems for Hostile Waters", PETROLEUM ENGINEER, September 1974

5. Childers, M. A. "Environmental Factors Control Station Keeping Methods", PETROLEUM ENGINEER, September 1974

6. Childers, M.A. "The Ultradeep Water Spread Mooring System", PETROLEUM ENGINEER, October 1974

7. Childers, M.A. "Equipment for Handling the Ultradeep Water Spread Mooring System", PETROLEUM ENGINEERING, May 1975

8. Krogstad, I. "New Chain/wire Mooring Systems Meet Challenge of Ultradeep Water", The Oil and Gas Journal, January 17, 1977

9. Preliminary OCEAN RANGER Booklet of Operating Conditions bearing U. S. Coast Guard approval stamp dated 13 December 1979

HULL DIGITIZING:

10. ODECO Dwg., unnumbered, OCEAN RANGER General Configuration from Operating Manual

11. MHI Dwg. No. G-0103, Sheet 3 of 8, Rev. 0 - General Arrangement - Lower Hull Exterior Fitting

WIND HEEL ANALYSIS:

MHI Dwgs. Nos.

12. G-0103, Sheet 3 of 8, Rev. 0 - Lower Hull Stbd. Exterior Fitting

13. G-0103, Sheet 6 of 8, Rev. 0 - Upper Deck and Drill Floor, General Arrangement

14. W-0162, Sheet 2 of 4, Rev. A - Hazardous Area Plan, Starboard Elevation

15. W-0162, Sheet 3 of 4, Rev. A - Hazardous Area Plan, Forward Elevation

INTACT STABILITY REVIEW (Original Study)

MHI Dwgs. Nos.

16. 1104, Rev. A - Curves of Form

17. 1105, Sheets 1-5, Rev. 0 - Cross Curves of Stability

18. 1106, Rev. A - Wind Heel Moment Curves

Submitted, 27 May 1982

W. A. HENRICKSON, LT, USCG
Eighth Coast Guard District (mmt)

APPENDIX 4

AN EVALUATION OF THE EFFECT OF THE SEAWAY ON THE MODU OCEAN RANGER IN A SEVERE STORM

(USCG)

DRAFT

AN EVALUATION OF THE EFFECT OF THE SEAWAY ON THE MODU OCEAN RANGER IN A SEVERE STORM

Prepared by
Marine Technical and Hazardous Materials Division
Office of Merchant Marine Safety
United States Coast Guard

August 1982

For
The Marine Board of Investigation

DRAFT

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INTRODUCTION

The U.S. owned Mobile Offshore Drilling Unit (MODU) OCEAN RANGER sank about 170 nautical miles off the coast of the Canadian Province of Newfoundland in a severe storm on 15 February 1982. The early morning casualty took the lives of 84 persons. The Commandant of the Coast Guard convened a Marine Board of Investigation. Similar investigations are underway under the auspicies of Transport Canada (Canadian Coast Guard) and the Province of Newfoundland and Laborador.

The Board asked the Marine Technical and Hazardous Materials Division to perform a number of studies. These include:

- Extensive investigation of the stability;
- Effect of the seaway related to flooding of the chain locker;
- Ballast system and pumping capabilities under listing conditions;
- Survival system equipment conditions.

This study (the second above) was an extension of the first. The results are provided in this report. It is organised as follows: an explanation of the approach, the questions asked by the Board - along with answers, the results of the study, and the assumptions. There are two appendices: one on the wave climatology and another detailing the results of the simulation runs.

STATEMENT OF THE PROBLEM

To aid the Marine Board in their investigation into the sinking of the OCEAN RANGER, the Office of Merchant Marine Safety was asked to perform some studies related to wave effects (a).

The studies reported here are an extension of a study conducted by the Eighth Coast Guard District (mmt)(b). Their report evaluated the static stability of the OCEAN RANGER under a variety of scenarios.

(a) Letter from the Marine Board of Investigation to Chief, Marine Technical and Hazardous Materials Division, dated 28 May 1982.

(b) Henrickson, W.A., "Report on the Stability of the MODU OCEAN RANGER," Eighth Coast Guard District (mmt), 27 May 1982, Board Exhibit 43.

APPROACH

To provide the Board with a credible tool to aid in analysis of the loss of the OCEAN RANGER, we have chosen a simple approach to describing wave theory. Numerous assumptions were necessary, but these have all been documented for further review by the Board.

The approach is based on the definition of significant wave height: the average of one-third highest waves. In each hour there will be about 360 waves of varying heights. Through many years of studies and full scale measurements the statistical nature of each hour of waves has been quantified. The wave heights follow a so called Rayleigh distribution (c, d).

The one-third highest waves were then divided into six wave groups. The highest wave group was twice the significant wave height. Figure 1 illustrates the distribution of these six wave groups for 30, 35, 40 and 45 foot significant wave heights. The figure shows the magnitude of the amplitude (one-half the wave height) that is compared to the freeboard of the platform.

In order to answer the Board's questions relating to the time a simple simulation computer program was developed for use on the PDP/11-34 computer which is part of the Coast Guard Maneuvering Simulator (e). This program determines the number of green water occurrences in each five minutes on an hour-by-hour basis. Figure 2 shows a schematic of the six wave groups that comprise the one-third highest waves for a 35-foot significant wave, poised with the OCEAN EXPRESS at a 15 degree list.

(c) Gran, S., "Statistical Description of Wave Induced Vibratory Stresses in Ships," CG-M-2-81, December 1980, NTIS AD A111186.

(d) Lindemann, K., "Summary of a Course in Shiphandling in Rough Weather," CG-M-7-81, September 1981, NTIS AD A115175.

(e) Walden, D.A. and Gress, R.K., "A Survey of Coast Guard Simulator Development Research and Simulator Applications," MarSim 81, Kings Point, New York, June 1981.

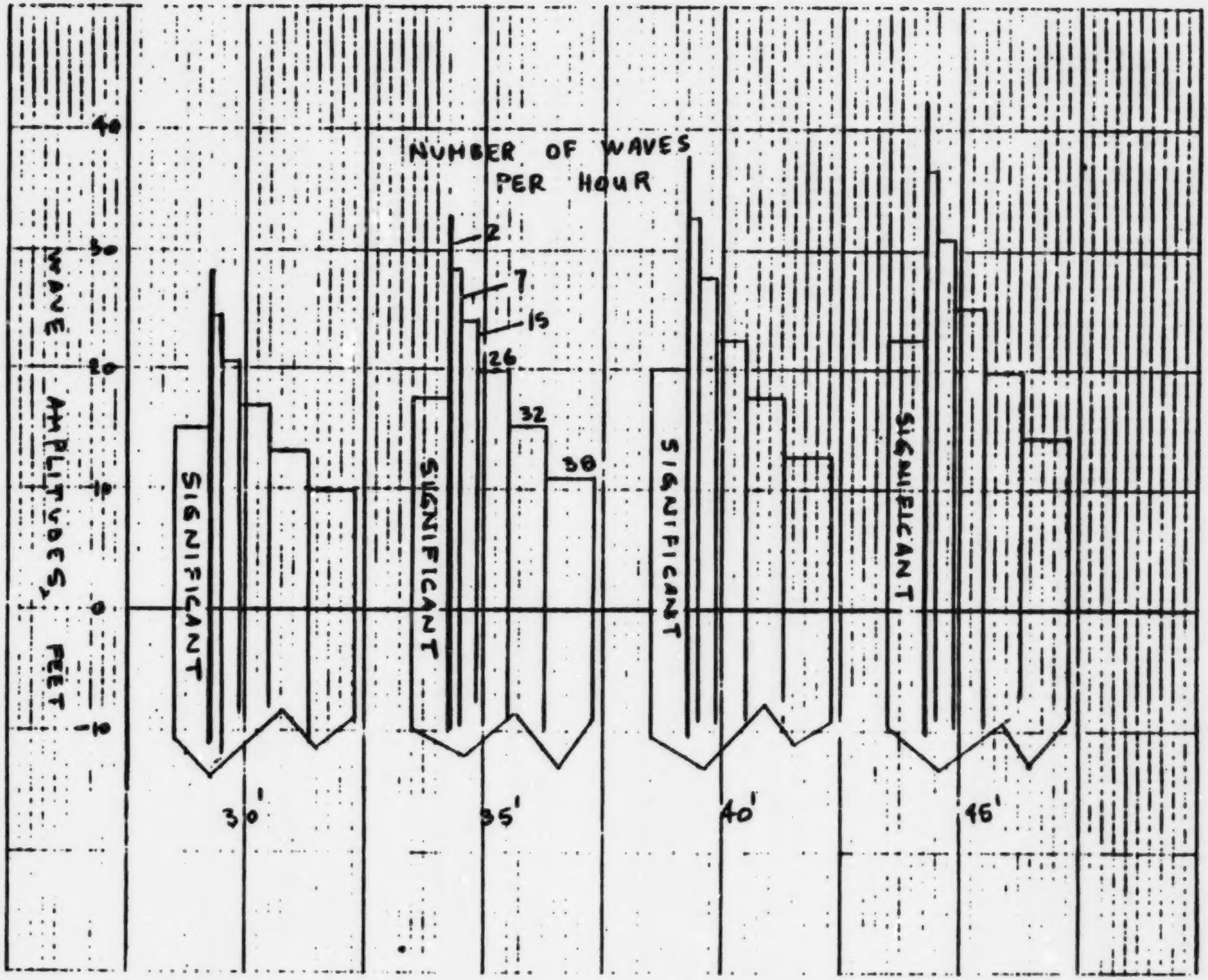


Figure 1 - Six Wave Groups for Four Significant Wave Heights

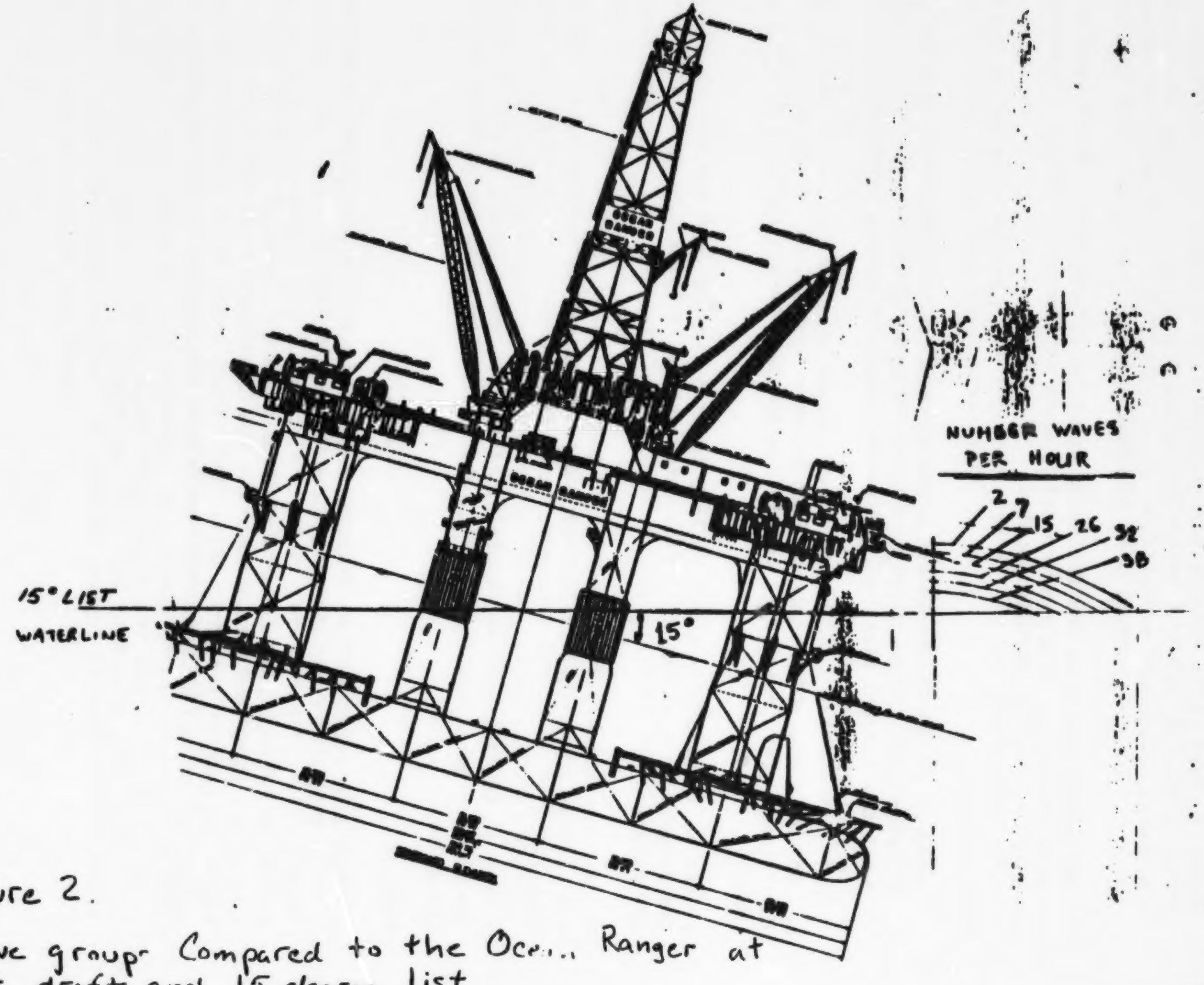

NUMBER WAVES PER HOUR
2
7
15
26
32
38
15° LIST
WATERLINE
15°

Figure 2.

Six wave group Compared to the Ocean Ranger at 80 feet draft and 15 degree list

TASKS

The Board requested the following specific information. Their questions are provided below, with answers and a short explanation. For more detailed explanation, see the results section.

Task I

> At what static list angle will significant green water begin to enter the forward port column chain pipe and wire trunk openings, and at what angle will the forward starboard column chain pipe and wire trunk openings begin to fill with water.

a. At an initial list angle of 14.5 degrees (and a draft of 80 feet) significant green water will begin to enter the forward port column chain locker.

b. At an initial list angle of 15.0 to 15.5 degrees (and a draft of 80 feet) the forward port column will fill, and eventually bring the upper hull down to the water.

c. At an initial list angle of 13.0 degrees (and a draft of 85 feet) significant green water will begin to enter the forward port column chain locker.

d. At an initial list angle of 13.5 to 14.0 degrees (and a draft of 85 feet) the forward port column will fill, and eventually bring the upper hull down to the water.

TASK II

> How long would it take to fill the forward port column chain locker using the initial static list angle determined in Task I?

a. At an initial list angle of 15 degrees (and a draft of 80 feet) it would take about three and a half hours for sufficient water to enter the chain locker to immerse the upper hull. Sufficient water would enter the chain locker in one and half hours at an initial list angle of 15.5 degrees.

b. At an initial list angle of 13.5 degrees (and a draft of 85 feet) it would take about two and a half hours for sufficient water to enter the chain locker to immerse the upper hull. Sufficient water would enter the chain locker in one and half hours at an initial list angle of 14.0 degrees.

TASK III

Assuming the port column chain locker filled within two hours, what would the initial static list angle have been?

a. An initial list angle of 15.5 degrees would result in immersion of the hull for an initial 80 foot draft. The weight of water in the chain locker was 105 long tons (10 percent of total capacity).

b. An initial list angle of 14.0 degrees would result in immersion of the hull for an initial 85 foot draft. The weight of water in the chain locker was 90 long tons (8 percent of total capacity).

TASK IV

Assuming a 12 degree initial list angle, how long would it take to fill the port column chain locker?

An initial list angle of 12 degrees would not result in significant green water in the vicinity of the anchor windlass for either the 80 or 85 feet drafts. There would be significant green water in the vicinity of the anchor windlass for the 80 feet draft at an initial list angle of 12 degrees if a 42 significant wave height was assumed.

RESULTS

The major results of the simulation are provided in Figure 3. This figure is a plot of the freeboard as a function of the local time, starting at 2100 (which is 0030 Greenwich Standard Time) for five different initial list angles - 14.0 through 16.0 degrees. When the freeboard is reduced to 21.5 feet, the upper hull is assumed to be immersed, and the simulation is stopped.

As an example of the process, we draw the readers attention to the curve for an initial list angle of 14.5 degrees. The steady reduction in freeboard before 0200 is caused by two green water occurrences per hour. At 0200, the freeboard has been sufficiently reduced to cause the next wave group (of seven per hour) to enter the chain locker. At 0300 the weight of water in the chain locker has increased to 95 long tons.

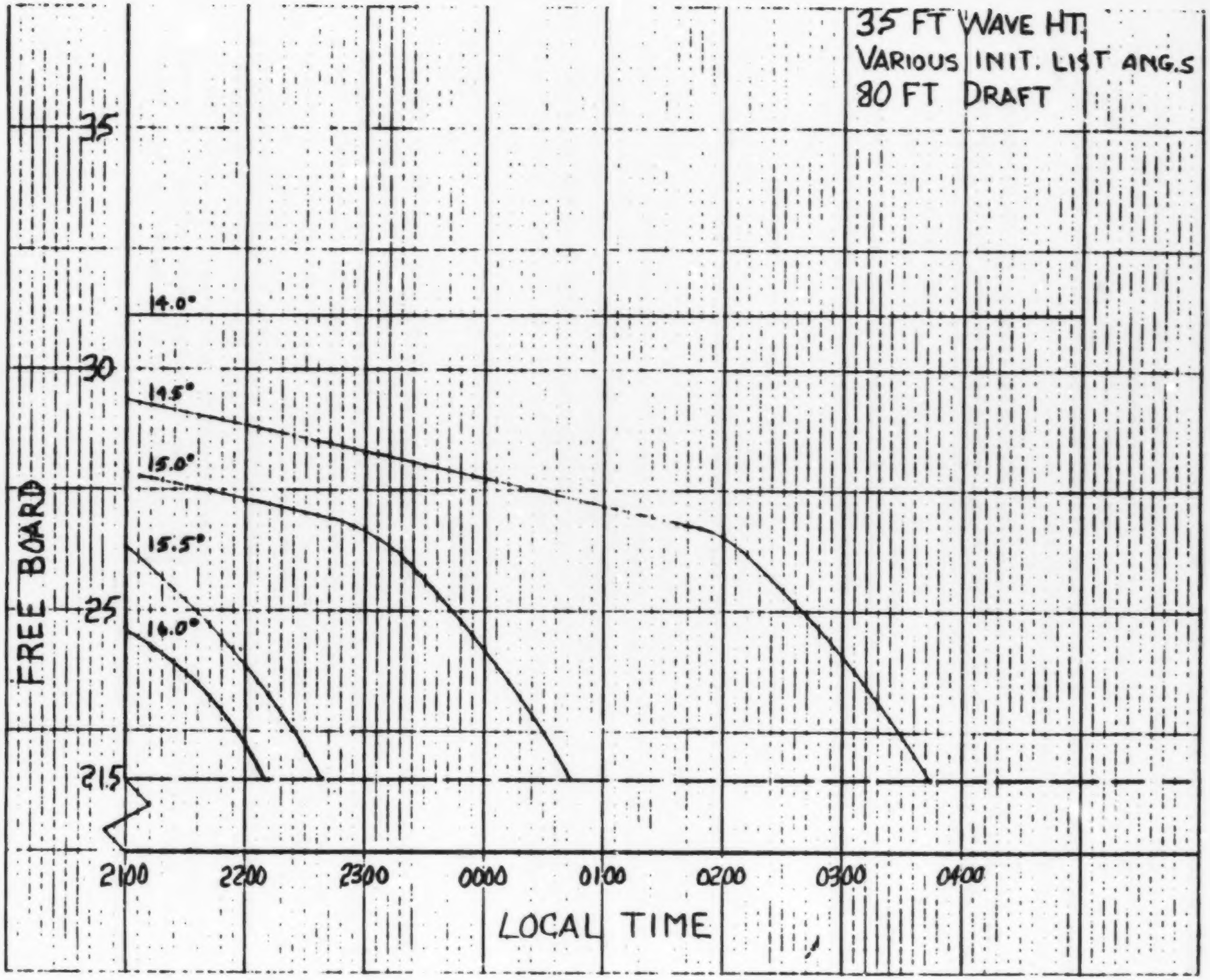


Figure 3 — Comparison of Freeboard with Time for 80 feet draft

To illustrate the sensitivity of the assumed wave conditions Figure 4 provides the freeboard for the RANGER at a draft of 80 feet with an initial list of 15 degrees. The three curves are for a significant wave height of 35 feet (as used for figure 3), and 30 and 40 feet.

Figure 5 is similar to Figure 3, but at an initial draft of 85 feet. rather than 80 feet.

Figure 6 provides the initial list angles for 80 feet of draft in a 40 feet significant wave height.

At a draft of 80 feet and no initial list, it would require a significant wave height of 80 feet for any green water occurrences. With an initial list angle of 5 degrees, a significant wave of 65 feet would be required for any green water occurrences.

ASSUMPTIONS

1. The analysis was conducted considering only static effects. The effects of heave and roll were neglected.

2. Throughout this report list is used to indicate a combination of heel and trim about the 45 degree axis.

3. Wind effects were not directly considered. The initial angle of list was assumed to be caused by ballast shifting, wind heel, or a combination of both. The actual cause of the initial list was not important to this analysis. List was assumed to occur about an axis 45 degrees from the centerline.

4. The simulation was run for a maximum time period of seven hours, or when the bottom of the upper hull entered the water whichever occurred first.

5. In order for green water to enter the chain locker, it was assumed that the wave amplitude must be at least two feet greater than the freeboard. For a two foot head of water over the chain locker openings with a total area of 31 square feet, approximately five tons of water will enter the chain locker. It was assumed that the deck machinery would restrict the inflow such that a head greater than two feet over the openings would not result in significantly greater flooding for each occurrence of green water. Therefore, it was assumed that for each occurrence of green water with a head of two feet or greater, five tons of water would enter the chain locker. A head of less than two feet would not result in any flooding.

6. List effects from flooding the chain locker included the effects of the moorings on the righting arm. Values for list angle versus weight in the chain locker were obtained from Henrickson's study. A piecewise linear relationship between list angle and weight of water in the chain locker was used.

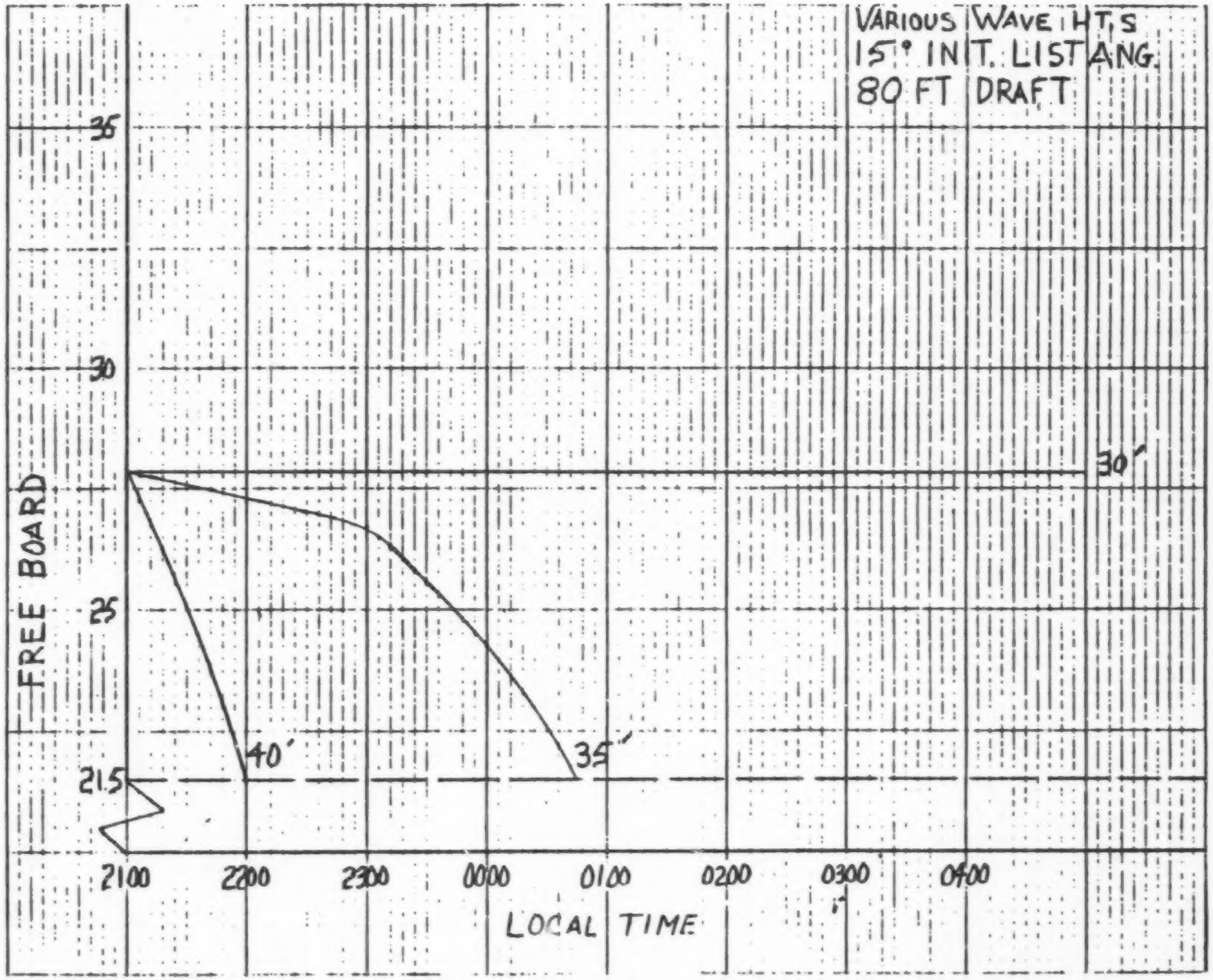


Figure 4 - Comparison of Freeboard with Time in Three Different wave Conditions

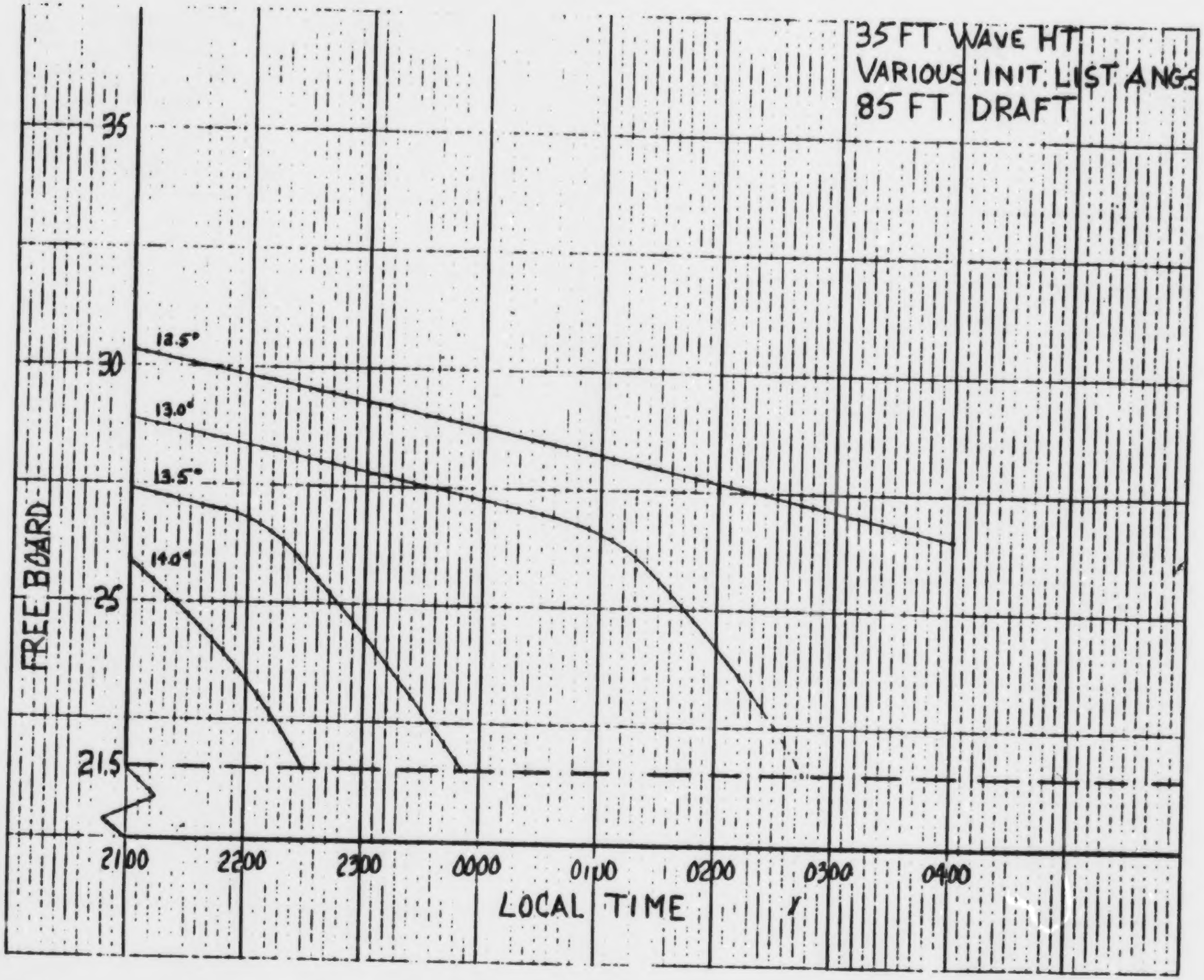


Figure 5 - Comparison of Free board with Time for 85 feet draft

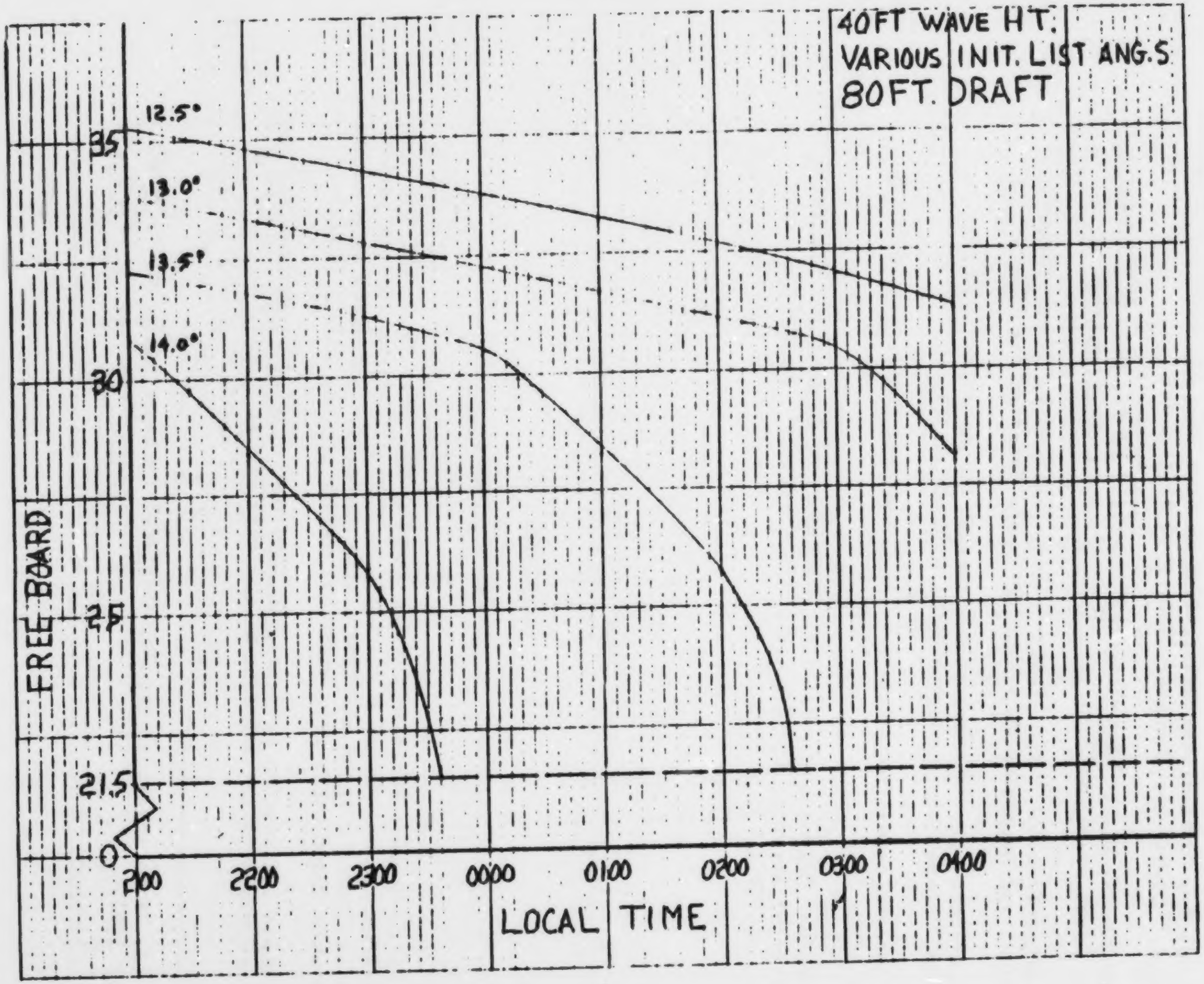


Figure 6 - Comparison of Freeboard with Time for 80 feet draft in more severe wave condition

REFERENCES

Gran, S., "Statistical Description of Wave Induced Vibratory Stresses in Ships," CG-M-2-81, December 1980, NTIS AD A111186.

Henrikson, W.A., "Report on the Stability of the MODU OCEAN RANGER," Eighth Coast Guard District (mmt), 27 May 1982, Board Exhibit 43.

Letter from the Marine Board of Investigation to Chief, Marine Technical and Hazardous Materials Division, dated 28 May 1982.

Lindemann, K., "Summary of a Course in Shiphandling in Rough Weather," CG-M-7-81, September 1981, NTIS AD A115175.

"Meteorological Report," Narional Transportation Safety Board, 7 April 1982.

Walden, D.A. and Gress, R.K., "A Survey of Coast Guard Simulator Development Research and Simulator Applications," MarSim 81, Kings Point, New York, June 1981.

APPENDIX

Wave Data for Study

Figure 7 is a location drawing showing the three MODUs off the coast of Newfoundland. Figure 8 provides the wave conditions for the period from 14 February up to the time of the casualty. The waves were recorded from wave rider buoys near the OCEAN RANGER and the ZAPATA UGLAND.

Table 1 gives the mean heights, and the range of amplitudes for the six waves groups for the four significant waves.

(f) "Meteorological Report," Narional Transportation Safety Board, 7 April 1982.

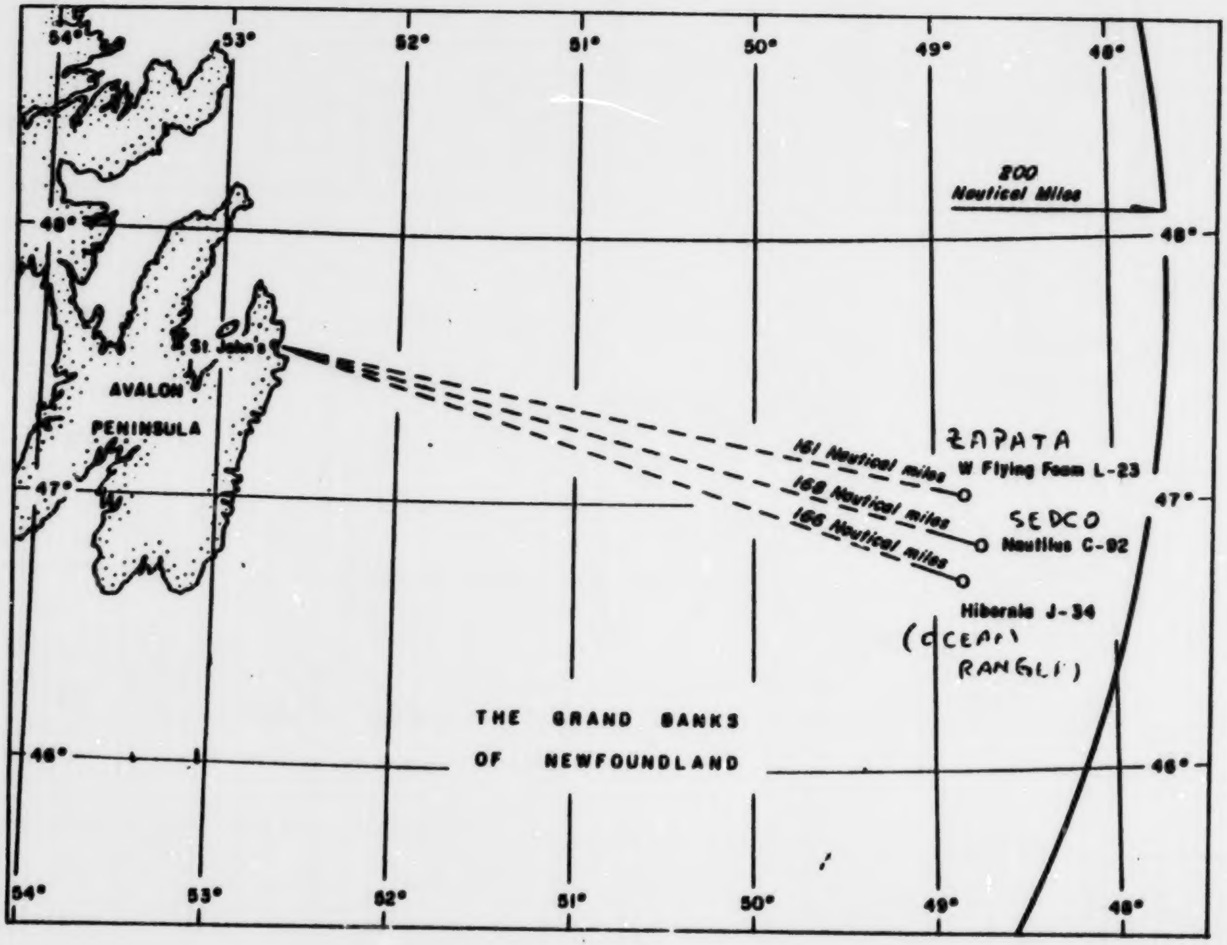

54°
53°
52°
51°
50°
49°
48°
47°
46°
200 Nautical Miles
St. John's
AVALON PENINSULA
161 Nautical miles
168 Nautical miles
166 Nautical miles
ZAPATA
W Flying Foam L-23
SEDCO
Nautilus C-92
Hibernia J-34
(OCEAN RANGER)
THE GRAND BANKS OF NEWFOUNDLAND

Figure 7 - Location of Platforms off Newfoundland, February 1982

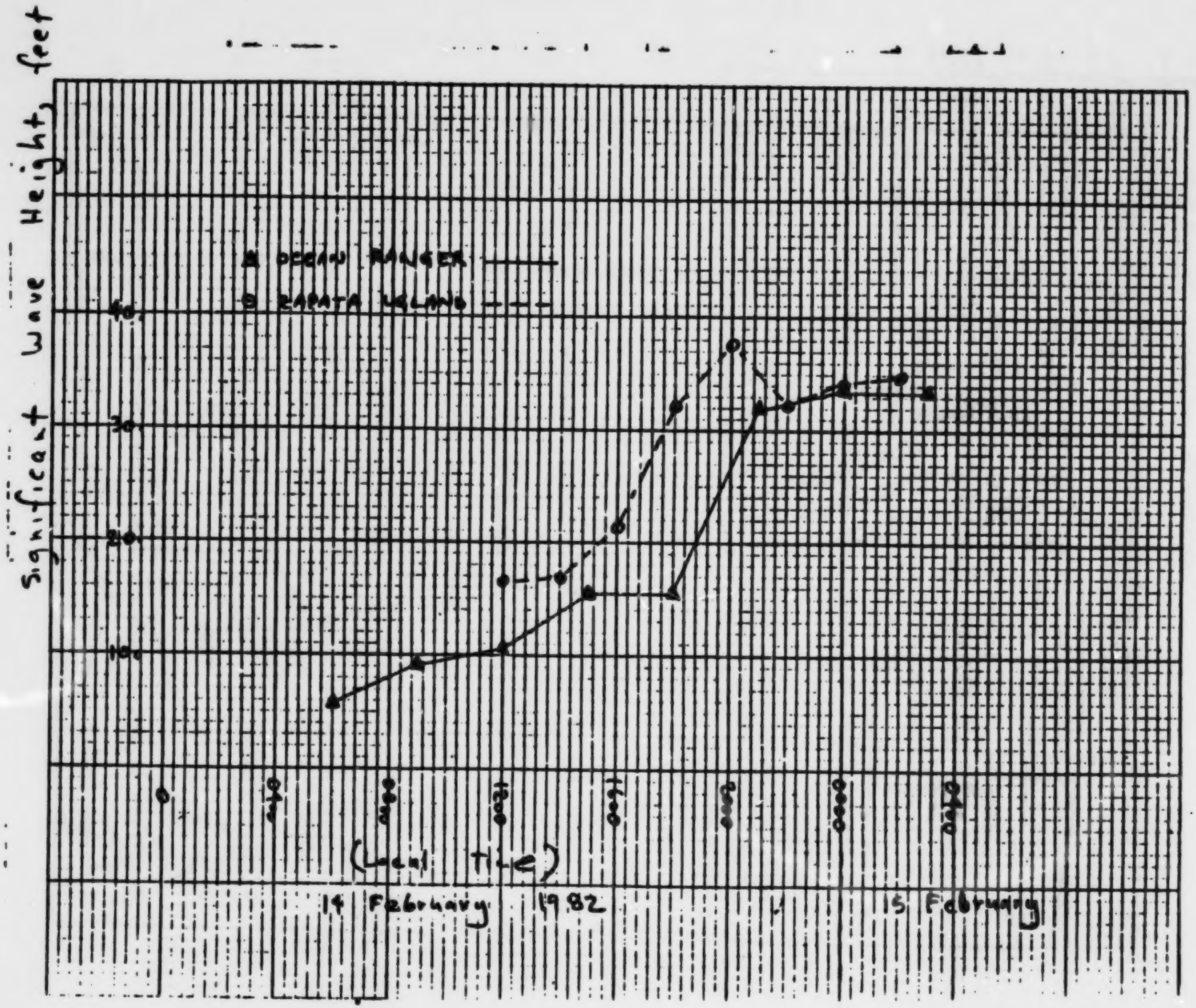


Figure 8 - Reported Wave Conditions, February 1982

TABLE 1

WAVE STATISTICS BASED ON THE SIGNIFICANT HEIGHT

30 FT SIGNIFICANT HEIGHT

MEAN HEIGHT	NO.
56.25	2
48.75	7
41.25	15
33.75	26
26.25	32
18.75	38

10 SEC. AVERAGE PERIOD

RANGE: HEIGHTS		RANGE: AMPLITUDES	
52.50	60.00	26.25	30.00
45.00	52.50	22.50	26.25
37.50	45.00	18.75	22.50
30.00	37.50	15.00	18.75
22.50	30.00	11.25	15.00
15.00	22.50	7.50	11.25

35 FT SIGNIFICANT HEIGHT

MEAN HEIGHT	NO.
65.62	2
56.88	7
48.13	15
39.38	26
30.63	32
21.87	38

10 SEC. AVERAGE PERIOD

RANGE: HEIGHTS		RANGE: AMPLITUDES	
61.25	70.00	30.63	35.00
52.50	61.25	26.25	30.63
43.75	52.50	21.87	26.25
35.00	43.75	17.50	21.87
26.25	35.00	13.13	17.50
17.50	26.25	8.75	13.13

40 FT SIGNIFICANT HEIGHT

MEAN HEIGHT	NO.
75.00	2
65.00	7
55.00	15
45.00	26
35.00	32
25.00	38

10 SEC. AVERAGE PERIOD

RANGE: HEIGHTS		RANGE: AMPLITUDES	
70.00	80.00	35.00	40.00
60.00	70.00	30.00	35.00
50.00	60.00	25.00	30.00
40.00	50.00	20.00	25.00
30.00	40.00	15.00	20.00
20.00	30.00	10.00	15.00

45 FT SIGNIFICANT HEIGHT

MEAN HEIGHT	NO.
84.37	2
73.13	7
61.88	15
50.63	26
39.38	32
28.12	38

10 SEC. AVERAGE PERIOD

RANGE: HEIGHTS		RANGE: AMPLITUDES	
78.75	90.00	39.38	45.00
67.50	78.75	33.75	39.38
56.25	67.50	28.12	33.75
45.00	56.25	22.50	28.12
33.75	45.00	16.88	22.50
22.50	33.75	11.25	16.88

APPENDIX

Results of Simulation Runs

The results of the simulation are provided in Table 2. They include the time for the upper hull to immerse, and the final trim conditions at the end of each simulation. It should be noted that the greatest weight of water in the chain locker was just over 200 long tons.

Table 3 is an sample simulation; for the 15 degrees of initial trim angle at a draft of 80 feet.

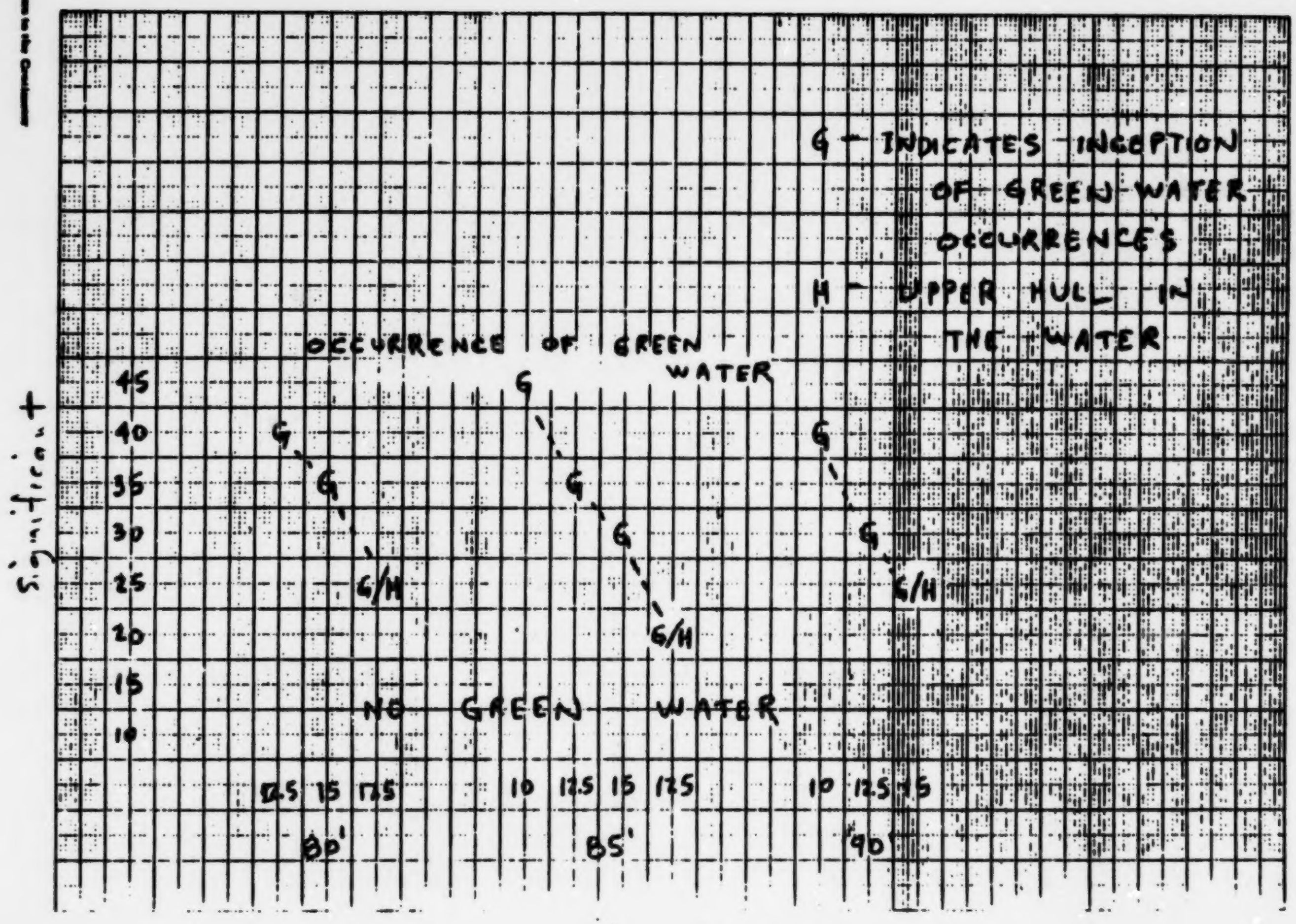


Figure 9 - Occurrence of Green Water for Various Drafts and List Angles

TABLE 3 SAMPLE SIMULATION

```
                                                    02-AUG-8    213:55:22

                      WAVE STATISTICS BASED ON THE SIGNIFICANT HEIGHT
                             SIGNIFICANT (FT)     AVERAGE PERIOD (SEC)

                          35.00                      10.00
       MEAN HEIGHT  NO.    RANGE: HEIGHTS, AMPLITUDES

    65.62         2
    56.88         7               61.25     70.00     30.63     35.00
    48.13        15               52.50     61.25     26.25     30.63
    39.38        26               43.75     52.50     21.87     26.25
    30.63        32               35.00     43.75     17.50     21.87
    21.87        39               26.25     35.00     13.13     17.50
    34.05       120               17.50     26.25      8.75     13.13
 HRS.MIN.SEC    DRAFT              17.50     70.00      8.75     35.00
                          LIST     TRIM      DISPL   LOCKER    GR WATER

   21. 0.00     80.00     15.00     27.83    38940.0      0.0
   21. 5.00     80.00     15.00     27.83    38940.0      0.0      0
 [illegible] [illegible]  15.00     27.83    38940.0      0.0      0
   21.15.00     80.03     15.08     27.55    38945.0      5.0      1
   21.20.00     80.06     15.16     27.28    38950.0     10.0      1
   21.25.00     80.06     15.16     27.28    38950.0     10.0      0
   21.30.00     80.06     15.16     27.28    38950.0     10.0      0
   21.35.00     80.06     15.16     27.28    38950.0     10.0      0
   21.40.00     80.06     15.16     27.28    38950.0     10.0      0
   21.45.00     80.06     15.16     27.28    38950.0     10.0      0
   21.50.00     80.06     15.16     27.28    38950.0     10.0      0
   21.55.00     80.06     15.16     27.28    38950.0     10.0      0
   21.60.00     80.06     15.16     27.28    38950.0     10.0      0

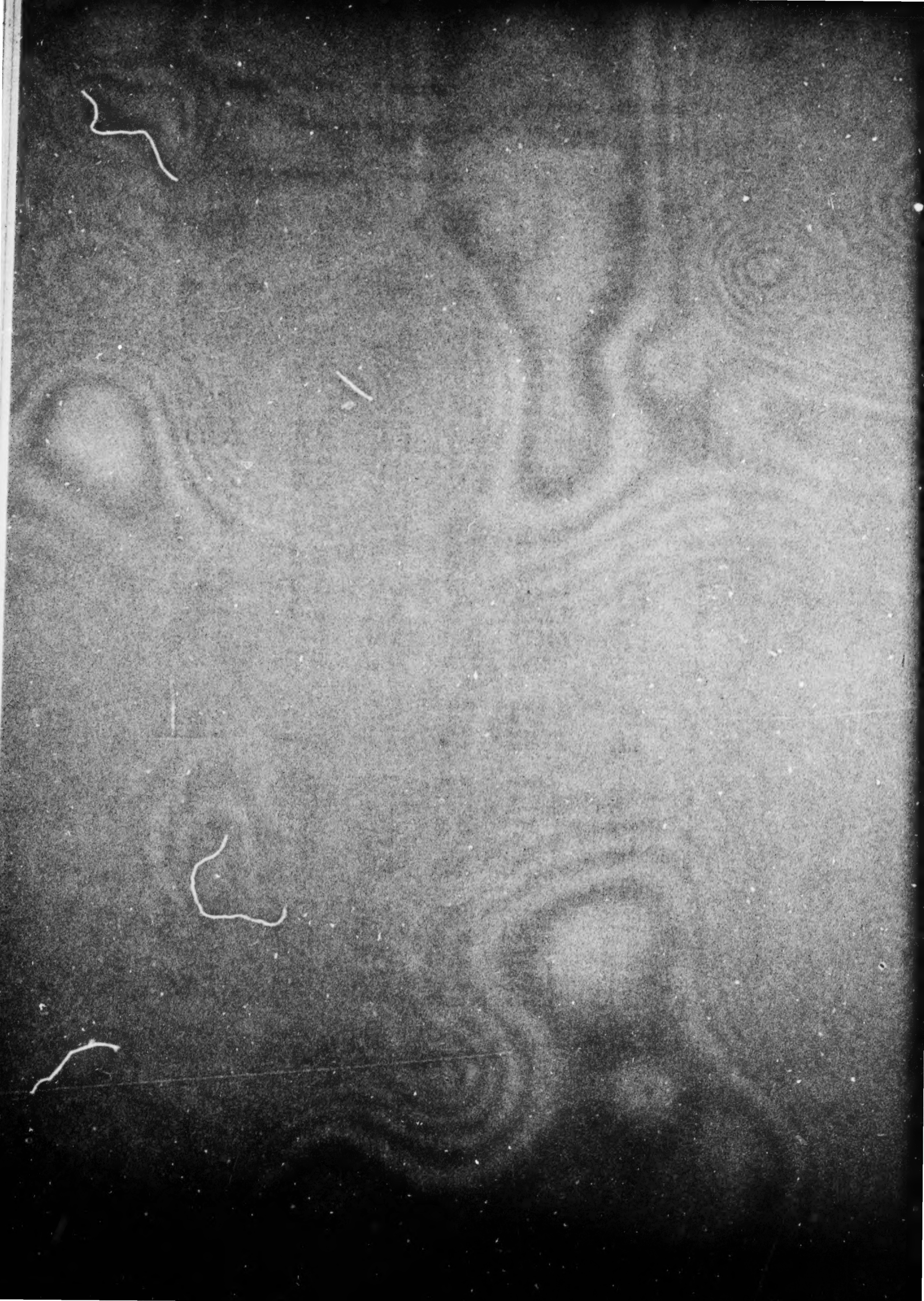
   22. 5.00     80.06     15.16     27.28    38950.0     10.0      0
   22.10.00     80.06     15.16     27.28    38950.0     10.0      0
   22.15.00     80.08     15.24     27.00    38955.0     15.0      1
   22.20.00     80.11     15.32     26.73    38960.0     20.0      1
   22.25.00     80.11     15.32     26.73    38960.0     20.0      0
   22.30.00     80.11     15.32     26.73    38960.0     20.0      0
   22.35.00     80.11     15.32     26.73    38960.0     20.0      0
   22.40.00     80.11     15.32     26.73    38960.0     20.0      0
   22.45.00     80.11     15.32     26.73    38960.0     20.0      0
   22.50.00     80.11     15.32     26.73    38960.0     20.0      0
   22.55.00     80.11     15.32     26.73    38960.0     20.0      0
   22.60.00     80.11     15.32     26.73    38960.0     20.0      0

   23. 5.00     80.11     15.32     26.73    38960.0     20.0      0
   23.10.00     80.11     15.32     26.73    38960.0     20.0      0
   23.15.00     80.14     15.40     26.45    38965.0     25.0      1
   23.20.00     80.17     15.49     26.17    38970.0     30.0      1

   23.25.00     80.20     15.57     25.90    38975.0     35.0      1
   23.30.00     80.23     15.65     25.62    38980.0     40.0      1
   23.35.00     80.25     15.73     25.34    38985.0     45.0      1
   23.40.00     80.28     15.81     25.07    38990.0     50.0      1
   23.45.00     80.31     15.89     24.79    38995.0     55.0      1
   23.50.00     80.34     15.97     24.51    39000.0     60.0      1
   23.55.00     80.37     16.05     24.23    39005.0     65.0      1
   23.60.00     80.37     16.05     24.23    39005.0     65.0      0

    0. 5.00     80.39     16.13     23.96    39010.0     70.0      1
    0.10.00     80.42     16.22     23.68    39015.0     75.0      1
    0.15.00     80.45     16.30     23.40    39020.0     80.0      1
    0.20.00     80.48     16.38     23.12    39025.0     85.0      1
    0.25.00     80.51     16.46     22.84    39030.0     90.0      1
    0.30.00     80.53     16.54     22.57    39035.0     95.0      1
    0.35.00     80.56     16.62     22.29    39040.0    100.0      1
    0.40.00     80.59     16.70     22.01    39045.0    105.0      1

    0.45.00     80.73     17.11     20.61    39070.0    130.0      5
             UPPER HULL IS NOW IN THE WATER
             * * END OF SIMULATION * *
```



APPENDIX 5

BALLAST TRANSFER RATES

(PETROLEUM DIRECTORATE)

Calculations

The Effect of Gravity
on
The Rate of Ballast Transfer

for

Mobil Offshore Drilling Unit

The Ocean Ranger

Conclusions

The effect of gravity on the rate of ballast transfer from port tank (P.T.) 10 to P.T. 4 while trimming from 0° to 11° by the bow is that it will take approximately 1 hour and 50 min. to transfer 610 L.Tons. The transfer was complete at a trim of 10.6°. It should be noted that familiar results depend upon the initial assumptions made.

Tabulated Results

Initial Time per Degree	5.7 min.
Final Time per Degree	19.9 min.
Total Time Required to Transfer 610 L.Tons	109.5 min.

General

All ballast tanks are connected to a common manifold through one remotely operated valve (ROV) for each tank. Flow between two tanks is possible with the respective ROV's for the two tanks in an open position. Gravity flow from port tank (P.T.) 10 to P.T. 4 would take place with ROV's P10 and P4 in an open position.

Prior to the accident ballast tank P.T. 10 was full while P.T. 4 was filled to only 4.5 percent of its capacity. The diving survey after the accident found P.T. 10 empty and P.T. 4 full. Opening ROV's P 10 and P 4 would of created a hydrostatic pressure difference causing water to transfer from P.T. 10 to P.T. 4 until the inclined water surface reached the ballast pipe bell mouth in P.T. 10. This transfer of ballast caused a forward trim of 11.0° with a V.C.G. of 63' (19.2m). This reduces the freeboard to the most forward chain pipe, without valves. The time for gravity transfer from P.T. 10 to P.T. 4 is determined in this Appendix.

Assumptions

The following assumptions were made in this appendix so that the approximate rate of ballast transfer could be obtained.

1. Quasi-steady flow conditions are to be dealt with.
2. There is a linear relationship between ballast transfer and trim, after the rig begins to trim.
3. Tanks P.T. 4 and P.T. 10 are wallsided.

Required Information

	Capacity Cap (ft^3)	LCG from (ft.)	100 Full Weight Salt Water @ 35 cu. ft./L. Ton	Max. Depth d (ft)
P.T. 4	28,581	95.14F	816.6	35
P.T. 10	24,871	18.13A	710.6	35

A_1 (average area of P.T. 10) = Cap/d = 24871 / 35
= 710.6 $ft.^2$
= 66.0m^2

A_2 (average area of P.T. 4) = Cap/d = 28581 / 35
= 816.6 $ft.^2$
= 75.9m^2

A_0 (area of pipe, dia = 0.2m) = 0.031m^2

f (friction factor) .

The friction factor can be determined from the moody chart (Friction factor vs. Reynolds Number with Relative Roughness as a Parameter).

Relative roughness was determined from Figure 41 of McGraw Hill Piping Handbook.

relative roughness -------- e/d = 0.00075

friction factor ----------- f = 0.0047

. See Reference (1)

Required Information Continued

Piping Particulars

From P.T. 10 to P.T. 4 (excluding common header).

l (length of pipe) = 88.325m

#Angles	Type
5	90°
16	45°

Total Equivalent Length

le (equivalent lenght of pipe fitting loss) = kd / 4f

for: 45° elbows -------- k = 0.4
90° elbows -------- k = 0.9

$le = [(0.9 \times 5 \times 0.2) / (4 \times 0.0047)] + [(0.4 \times 16 \quad 0.2) / (4 \times 0.0047)]$

l_T (length total) = l + le
= 88.325m + 115.957m
= 204.282m

D (Distance Between Tank Centres) = [95.14 F + 18.13 A] ft.
= 113.27 ft. between tanks
= 34.52 m

(Additional hydrostatic head due to trim) = 34.52 sine m

Initial level difference

where: P.T. 4 Area (A_2) = 816.6 $ft.^2$
Volume (Vol) = (28581.0 $ft.^3$) x (0.045)
Vol / A_2 = 1.57 ft.

P.T. 10 100 percent full 35.00 ft. (depth of tank)
P.T. 4 4.5 percent full - 1.57 ft.
= 33.42 ft. (10.19m)

. See Reference (2) a (4)

Required Information Continued

(loss in P.T. 4 head per L.T.) = 35 ft.^3 / L.T. x (1 / 816.60 ft.^2)
= 0.043 ft. / L.T.
= 0.013 m / L.T.

(loss in P.T. 10 head per L.T.) = 35 ft.^3 / L.T. x (1 / 710.6 ft.^2)
= 0.049 ft. / L.T.
= 0.015 m / L.T.

Transfer of L.T. with respect to θ.

Assuming a linear relationship between ballast transfer and trim, after the rig has initially begun to trim.

# L. Tons α θ
# L. Tons = $K\theta$

where K_1 = 610 L.T. / 11
= 55.454 L.T. / ( )°

L. Tons = 55.454 θ L.T.

Rate of Ballast Transfer

Quasi - steady flow

$$t = -\int_{H_1}^{H_2} \left\{ A_1 / [C \cdot \sqrt{H} \ (1 + A1/A_2)] \right\} dH.$$

where:

$$C = A_0 \sqrt{[2g/(4 \ fl_T/d + k)]}$$

(k is taken into account with total effective pipe length)
($g = 9.81 \ m/s^2$)

$$C = (0.031 m^2) \sqrt{[(2 \times 9.81 m/s^2)/(4 \times 0.0047 \times 204.282 m/0.2 m)]}$$
$$= .031$$

H (hydrostatic head due to trim) = (initial level difference)
− (loss in P.T. 4 Head per L.T.)
− (loss in P.T. 10 Head per L.T.)
+ (additional Head due to trim)

$$H = [10.19 \ m] - [0.013 \ m / L.T. \times 55.454 \ \theta \ L.T.] - [0.015 \ m / L.T. \times 55.454 \ \theta \ L.T.] + [34.52 \sin\theta \ m]$$

$$= [10.19m] - [1.553 \ \theta] + [34.52 \sin\theta]$$

$$\frac{-A_1 \frac{dH}{dt}}{\left(1 + \frac{A_1}{A_2}\right)} = c\sqrt{H}$$

$$dt = \frac{-A_1}{c\left(1 + \frac{A_1}{A_2}\right)} (H)^{-1/2} \ dH.$$

$$t = \frac{-A_1}{c\left(1 + \frac{A_1}{A_2}\right)} \int_{H_1}^{H_2} (H)^{-1/2} dH$$

. See Reference (3)

Ballast Transfer Rate Continued

where:

$$H = 10.19 - 1.553\,\theta + 34.52 \sin\theta.$$

$$\frac{dH}{d\theta} = -1.553 + 34.52 \cos\theta$$

$$t = \frac{-A_1}{C\left(1+\frac{A_1}{A_2}\right)} \int_{\theta_1}^{\theta_2} \left[(10.19-1.553\,\theta + 34.52 \sin\theta)^{-1/2} \times (-1.553 + 34.52 \cos\theta)\right] d\theta$$

Let

$$u = (10.19 - 1.553\theta + 34.52 \sin\theta)$$

$$\frac{du}{d\theta} = (-1.553 + 34.52 \cos\theta)$$

$$t = \frac{-A_1}{C\left(1+\frac{A_1}{A_2}\right)} \int_{u_1}^{u_2} u^{-1/2}\, du$$

$$= \frac{-A_1}{C\left(1+\frac{A_1}{A_2}\right)} \left[\frac{u^{1/2}}{1/2}\right]_{u_1}^{u_2}$$

$$t = \frac{-2A_1}{C\left(1+\frac{A_1}{A_2}\right)} \left[u_2^{\,1/2} - u_1^{\,1/2}\right]$$

where:

$$\frac{-2A_1}{C\left(1+\frac{A_1}{A_2}\right)} = \frac{-2\,(66.0\text{m}^2)}{(0.031)\left(1+\frac{66.0\text{ m}^2}{75.9\text{ m}^2}\right)}$$

$$= -2255.6$$

Therefore:

$$t = -2255.6 \times \left[(10.19 - 1.553\,\theta 2 + 34.52 \sin\theta 2)^{1/2} - (10.19 - 1.553\,\theta 1 + 34.52 \sin\theta 1)^{1/2}\right]$$

Ballast Transfer Rate
Table

θ	t (min/( )°)	T (min)
0		
1	5.7	5.7
2	6.0	11.8
3	6.4	18.2
4	6.8	25.0
5	7.4	32.4
6	8.1	40.4
7	9.0	49.4
8	10.3	59.7
9	12.5	72.3
10	17.3	89.6
10.6	19.9	109.5

References

(1) *The Ocean Ranger Booklet of Operating Conditions*, by ODECO Engineers, Inc., - Pages G4, G8, I1

(2) *Piping Handbook*, 5th ed., copyright 1967 by McGraw-Hill, Inc. pages 3-126, 130.

(3) *Fluid Mechanics*, Douglas J.F., copyright 1979 by J.F. Douglas, Pittman Publishing Limited, London - pages 274, 275, 481.

(4) Drawings

	No.
General Piping Plan in Lower Hull Tanks	(P-4101) Rev. A
General Piping Plan in Lower Hull Pump Room	(P-4130) Rev. B